A Wireless Sensor Network for Monitoring of Water Level on Drainage Systems using ZigBee

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Bachelor of Science in Computer Engineering

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Approval Sheet

Mapua Institute of Technology

School of EECE

This is to certify that I have supervised the preparation of and read the design report prepared by **Ani, Meynard Frizth A., Chua, Divina A., Cuna, Michael John A.** entitled **A Wireless Sensor Network for Monitoring of Water Level on Drainage Systems using ZigBee** and that the said report has been submitted for final examination by the Oral Examination Committee.

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As members of the Oral Examination Committee, we certify that we have examined this design report, presented before the committee on **June 11, 2013**, and hereby recommended that it be accepted in fulfillment of the design requirements for the degree in **Bachelor of Science in Computer Engineering.**

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Abstract

Clogged drainage systems are the major cause of pollution and frequent flooding in Metro Manila especially during the rainy season. Thus, it is required to routinely monitor the condition of these drainage systems. The proposed system provides a way to monitor remotely drainage conditions and inform authorities of these conditions. This design presents an implementation of wireless sensor network in the monitoring of drainage systems using ZigBee. The use of ZigBee in wireless sensor network provides low cost, low power consumption, flexible and reliable network which is fast and easy to deploy. Blockages in drainage systems are detected through monitoring of water levels inside the drainage. The design consists of water level sensors which read the water levels and the ZigBee module is used to wirelessly send this information back to a central computer that monitors all drainages throughout the area.

Keywords: drainage systems, monitoring, wireless sensor network, ZigBee, water level

Chapter 1

DESIGN BACKGROUND AND INTRODUCTION

Clogging of drainage is a major cause of both flooding and pollution in Metro Manila. Flooding is one of the main problems in the metro. This problem can result to even bigger disasters, such as deaths and damage to properties. Hence, providing an early warning device is one of the measures to prevent such disasters. The detection of drainage condition is routinely required in order to be informed on the best course of action that provides a solution to this critical problem. According to the Metro Manila Development Authority (MMDA), drainage and sewerage functions are combined in other countries unlike here in the Philippines where it is separate. The sewerage handles human waste and other liquid waste coming from households, while the drainage handles liquid waste coming from streets, factories, creeks, etc. This design project is based on the areas being handled by the MMDA.

Some of the existing systems today are for flood detection and control. This proposed system is focused more towards prevention rather than control. In the article "Development of Robotic Sewerage Blockage Detector Controlled by Embedded Systems" (Shrivastava, 2012), a remote controlled robot is attached with sensors for monitoring blockages in sewer pipelines. They used ultrasound sensors to detect blockages. On the other hand, this design uses sensors to detect water and waste levels in the drainage, thereby allowing the possibility of detecting blockage in the waterway. This approach in detecting

blockages is different because water level sensors are used to detect overflow in the drainage. The introduction of wireless technology for flood monitoring will provide effective warning and response system. No manual checking will be needed because information about the water level is sent directly to a computer application.

The main objective of this study is to design a ZigBee-based wireless system that provides an easy way to monitor drainage conditions by water level. Specifically, the study aims to create a software application that gets and displays the current water level.

The scope of this design is to monitor the drainage condition using a ZigBee wireless network with water level sensors. The water level sensors are set to certain levels – i.e. high, medium, and low. These are used to monitor the water level condition. It is limited only to monitoring and does not include flood control. Another limiting factor of this design project is that it only detects flooding due to increasing water level and does not detect actual level of solid waste sediments.

This design will impact on providing a more prepared and safe environment, as well as the health and safety of the people in local cities. The design will be useful for monitoring flash floods too. Also, by using wireless sensor network for monitoring of drainage, a simple implementation of wireless technology is presented.

The implementation of ZigBee in wireless sensor networks has the following advantages: low power consumption, flexible and reliable network, and fast and easy deployment. ZigBee-based wireless sensor network will provide a means to monitor the drainage condition, and sends information back to a central server. This allows easy monitoring of the condition of the drainage and will allow authorities to accurately plan and carry out necessary actions.

Definition of Terms

Early Warning System - a system or procedure designed to warn of a potential or an impending problem.

Embedded Systems - a computer system with a dedicated function within a larger electrical system, often with real-time computing constraints.

FFD - full function device; a device which can route ZigBee packets as part of it's normal operation.

IEEE 802.15.4 - a standard which specifies the physical layer and media access control for low-rate wireless personal area networks.

MMDA - Metro Manila Development Authority; handles and maintains the area of Metro Manila Philippines.

Network Coordinator – a device that is responsible for coordinating all devices in the network.

Receiver - a device that receives incoming radio signals and converts them to perceptible forms, such as sound or light.

RFD - reduced function device; a device that cannot route ZigBee packets.

Sediments - matter that settles to the bottom of a liquid.

Sensor - a device that detects or measures a physical property and records, indicates, or otherwise responds to it.

Transmitter - set of equipment used to generate and transmit electromagnetic waves carrying messages or signals.

WPAN - wireless personal area network; a personal area network - a network for interconnecting devices centered around an individual person's workspace - in which the connections are wireless.

WSN - wireless sensor network; refers to a group of spatially dispersed and dedicated sensors for monitoring and recording the physical conditions of the environment.

ZigBee - a specification for wireless personal area networks operating at 868 MHz, 902-928 MHz, and 2.4 GHz.

Chapter 2

REVIEW OF RELATED DESIGN LITERATURES AND STUDIES

There has been little research regarding wireless sewer monitoring, many of the sewer monitoring systems today still use mechanical methods. Previous studies use ZigBee added with other signal technologies for monitoring. On the other hand, this study uses ZigBee, together with water sensor technology. The study is composed of three main parts: the water sensor, ZigBee, and the microcontroller unit. The chapter discusses all three of those as well as previous related studies that were used as reference for this study.

Wireless Sewer Monitoring

Sewer network is prevalent in all cities and towns and is an underground facility. Earlier sewer systems were designed using the masonry materials and the current sewer systems are designed using the pipes (Shrivastava, 2012). Sewer flooding and pollution incidents are significant issues in the wastewater business process in the water industry. One of the most pressing issues for prevention of sewer flooding and pollution is sewer and gully blockages. Monitoring and maintaining the sewer are important parts of many water companies business to prevent catastrophic failures that can shut down a facility. Currently, many water companies have deployed telemetry systems to replace some of the manual operations, running costs remain expensive. Low cost wireless sensors may be the only cost-efficient option to

replace traditional visual inspection which is extremely inefficient and costly. Low cost and low power sensors could be deployed over an extensive footprint network and provide early warning of impending failure offering time for maintenance teams to prevent service or regulatory compliance failure (Horoshenkov, Tait, Abd-Alhameed, Hu, Elkhazmi, Gardiner, 2009).

A practical implementation of a low-cost wireless Wireless Sensor Network (WSN) is by using Zigbee communication and acoustic sensor technologies to monitor the water level of the gullies. A Zigbee based short range WSN was selected for this application due to its attractive features such as low data rate, low power consumption, simple communication infrastructure, low latency and capability to support one master and up to 65000 slave control units.

There are two ways of using a sonic transmission to detect the water level, i.e. (i) by measuring the time of flight from transmitter to receiver – it will be faster in water, (ii) by using the level of the received signal – the received signal will be louder if the transmitter and receiver are both under water. Both of these methods of detection will require a driver for the acoustic transmitter and an amplifier for the received signal (Horoshenkov, Tait, Abd-Alhameed, Hu, Elkhazmi, Gardiner, 2009).

Liquid Level Sensor

Liquid level sensors detect the level of substances that flow, including liquids, slurries, granular materials, and powders. Fluids and fluidized solids flow to become essentially level in their containers (or other physical boundaries) because of gravity whereas most bulk solids pile at an angle of repose to a peak. The substance to be measured can be inside a container or can be in its natural form (e.g., a river or a lake). The level measurement can be either continuous or point values. Continuous level sensors measure level within a specified range and determine the exact amount of substance in a certain place, while point-level sensors only indicate whether the substance is above or below the sensing point. Generally, the latter detect levels that are excessively high or low (Deeter, 2009).

There are many physical and application variables that affect the selection of the optimal level monitoring method for industrial and commercial processes. The selection criteria include the physical: phase (liquid, solid or slurry), temperature, pressure or vacuum, chemistry, dielectric constant of medium, density (specific gravity) of medium, agitation, acoustical or electrical noise, vibration, mechanical shock, tank or bin size and shape. Also important are the application constraints: price, accuracy, appearance, response rate, ease of calibration or programming, physical size and mounting of the instrument, monitoring or control of continuous or discrete (point) levels.

LED and optoschmitt chips are sealed into the base of a clear plastic dome in such a position that light is normally, totally, internally reflected from the dome boundary to the optoschmitt. Thus, the output is normally high. When liquid covers the dome, the change is refractive index at the boundary means light escapes into the liquid, less light reaches the optoschmitt which turns off (Deeter, 2009).

ZigBee

ZigBee is a technology following IEEE 802.15.4 protocol. Low complexity, low cost, low power consumption, low transmitting rate, high reliability, wireless short distance transmission (compared with global Internet), and being capable of ad-hoc networks are all its features (Ruan Qiang, Xu Wengsheng, Wang Gaoxiang, 2011). ZigBee is a specification for wireless personal area networks (WPANs) operating at 868 MHz, 902-928 MHz, and 2.4 GHz. A WPAN is a personal area network (a network for interconnecting an individual's devices) in which the device connections are wireless. Using ZigBee, devices in a WPAN can communicate at speeds of up to 250 Kbps while physically separated by distances of up to 50 meters in typical circumstances and greater distances in an ideal environment. ZigBee is slower than Wi-Fi and Bluetooth, but is designed for low power so that batteries can last for months and years.

ZigBee provides for high data throughput in applications where the duty cycle is low. This makes ZigBee ideal for home, business, and industrial automation where control devices and sensors are commonly used. Applications

well suited to ZigBee include heating, ventilation, and air conditioning, lighting systems, intrusion detection, fire sensing, and the detection and notification of unusual occurrences. ZigBee is compatible with most topologies including peer-to-peer , star network , and tree networks, and can handle up to 255 devices in a single WPAN (Margaret Rouse, 2006).

The ZigBee offers three frequency bands, with 27 channels specified as follows. Table 2.1 shows a list of the features of these channels.

Table 2.1 ZigBee features

Frequency Band	Channels	Data Rate
868 and 868.6 MHz	Channel 0, 10	20 Kbps
902.0 and 928.0 MHz	Channel 1-10	40 Kbps
2.4 and 2.4835 GHz	Channel 11-26	250 Kbps

The principle of ZigBee is not very complex. Devices using ZigBee technology can automatically connect to other devices around them, and those RFID devices form a lot of data paths, so different nodes can transfer their information to the end-users through the different paths (Ruan Qiang, Xu Wengsheng, Wang Gaoxiang, 2011).

A ZigBee system consists of several components. The most basic is the device. A device can be a full-function device (FFD) or reduced-function device (RFD). A network shall include at least one FFD, operating as the personal area network (PAN) coordinator. The FFD can operate in three modes: a PAN coordinator, a coordinator or a device (Sinem Coleri Ergen, 2004). Figure 1.3

shows 3 types of topologies that ZigBee supports: star topology, peer-to-peer topology and cluster tree.

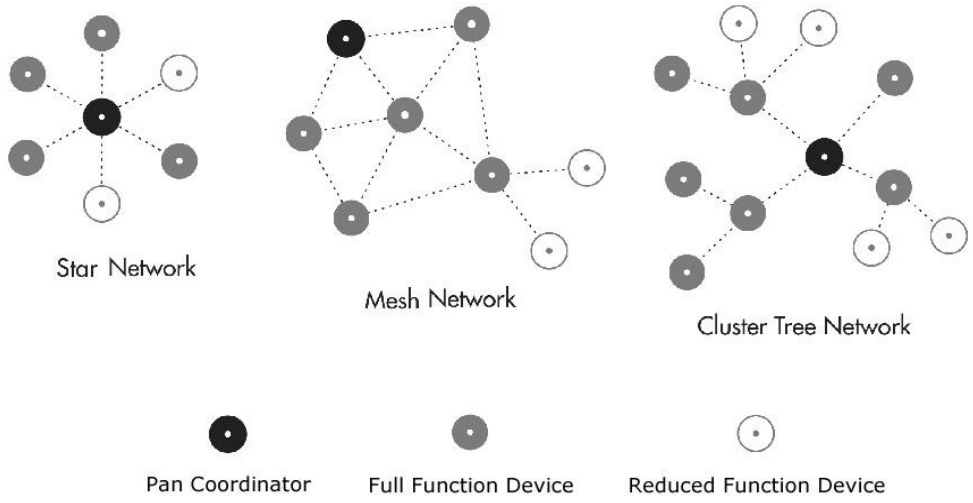

Figure 2.1 Topology Models

ZigBee devices are often used in mesh network form to transmit data over longer distances, passing data through intermediate devices to reach more distant ones. Mesh networking provides high reliability and more extensive range. This allows ZigBee networks to be formed ad-hoc, with no centralized control or high-power transmitter/receiver are able to reach all of the devices. Any ZigBee device can be tasked with running the network (Oziel Hernandez, Varun Jain, Suhas Chakravarty, Prashant Bhargava, 2010).

ZigBee and IEEE 802.15.4

ZigBee technology is a low data rate, low power consumption, low cost; wireless networking protocol targeted towards automation and remote control applications. IEEE 802.15.4 committee started working on a low data rate standard a short while later. Then the ZigBee Alliance and the IEEE decided to join forces and ZigBee is the commercial name for this technology.

ZigBee is expected to provide low cost and low power connectivity for equipment that needs battery life as long as several months to several years but does not require data transfer rates as high as those enabled by Bluetooth. In addition, ZigBee can be implemented in mesh networks larger than is possible with Bluetooth. ZigBee compliant wireless devices are expected to transmit 10-75 meters, depending on the RF environment and the power output consumption required for a given application, and will operate in the unlicensed RF worldwide (2.4GHz global, 915MHz Americas or 868 MHz Europe). The data rate is 250kbps at 2.4GHz, 40kbps at 915MHz and 20kbps at 868MHz (Sinem Coleri Ergen, 2004).

IEEE and ZigBee Alliance have been working closely to specify the entire protocol stack. IEEE 802.15.4 focuses on the specification of the lower two layers of the protocol (physical and data link layer). On the other hand, ZigBee Alliance aims to provide the upper layers of the protocol stack (from network to the application layer) for interoperable data networking, security services and a range of wireless home and building control solutions, provide interoperability

compliance testing, marketing of the standard, advanced engineering for the evolution of the standard (Sinem Coleri Ergen, 2004).

Microcontroller

Microcontroller is an integrated circuit that has a central processing unit, input/output interfaces, and peripherals such as timers, RAM, ROM, and a clock generator. PIC (Peripheral Interface Controller) is a family of modified Harvard architecture microcontrollers made by Microchip Technology. PICs are popular with both industrial developers and hobbyists alike due to their low cost, wide availability, large user base, extensive collection of application notes, availability of low cost or free development tools, and serial programming (and re-programming with flash memory) capability. One of the most useful features of a PIC microcontroller is that one can re-program it as it uses flash memory. One can either program a PIC microcontroller using an assembler or a high level language. PICs have a set of registers that function as general purpose RAM. Special purpose control registers for on-chip hardware resources are also mapped into the data space. ICSP (In Circuit Serial Programming) is the next most important benefit. Instead of transferring the chip from the programmer to the development board just leave it in the board. One can re-program the device while it's still in the circuit so once the programmer is setup you can leave it on the bench and test the programs without moving the chip around and it makes the whole process much easier.

The microcontroller executes the program loaded in its flash memory. This is the so called executable code that comprised of seemingly meaningless sequence of zeros and ones. It is organized in 12-, 14- or 16-bit wide words, depending on the microcontroller's architecture. Every word is considered by the CPU as a command being executed during the operation of the microcontroller (Milan Verle, 2009).

As the process of writing executable code was endlessly tiring, the first 'higher' programming language called assembly language was created. The truth is that it made the process of programming more complicated, but on the other hand the process of writing program stopped being a nightmare. Instructions in assembly language are represented in the form of meaningful abbreviations, and the process of their compiling into executable code is left over to a special program on a PC called compiler. The main advantage of this programming language is its simplicity, i.e. each program instruction corresponds to one memory location in the microcontroller. It enables a complete control of what is going on within the chip, thus making this language commonly used today (Milan Verle, 2009).

However, programmers have always needed a programming language close to the language being used in everyday life. As a result, the higher programming languages have been created. One of them is C. The main advantage of these languages is simplicity of program writing. It is no longer possible to know exactly how each command executes, but it is no longer of

interest anyway. In case it is, a sequence written in assembly language can always be inserted in the program, thus enabling it (Milan Verle, 2009).

PIC microcontrollers can be programmed in assembly, C or a combination of the two. Other high-level programming languages can be used but embedded systems software is primarily written in C (Yesu Thommandru, 2006). Although assembler is a common choice when programming small microcontrollers, it is less appropriate for complex applications on larger MCUs; it can become unwieldy and difficult to maintain as programs grow longer. A number of higher-level languages are used in embedded systems development, including BASIC, Forth and even Pascal. But the most commonly used "high level" language is C (David Meiklejohn, 2008).

Previous wireless sewer monitoring studies used Zigbee for communication and acoustic sensor technologies to monitor the water level. Another previous study used remote controlled robots with attached ultrasound sensors to monitor the sewer. Both of these used audio sensors to monitor the water level. The use of water level sensor, together with ZigBee has not been done for sewer monitoring. The study aims to design a sewer/drainage monitoring system using ZigBee and water level sensors.

Chapter 3

DESIGN PROCEDURES

The operation of the proposed active ZigBee based wireless sensor network for monitoring of drainage is to monitor the drainage condition for an early flood response. Figures 3.1 and 3.2 illustrate the block diagram of the water level sensor and the main server part of the design project, respectively.

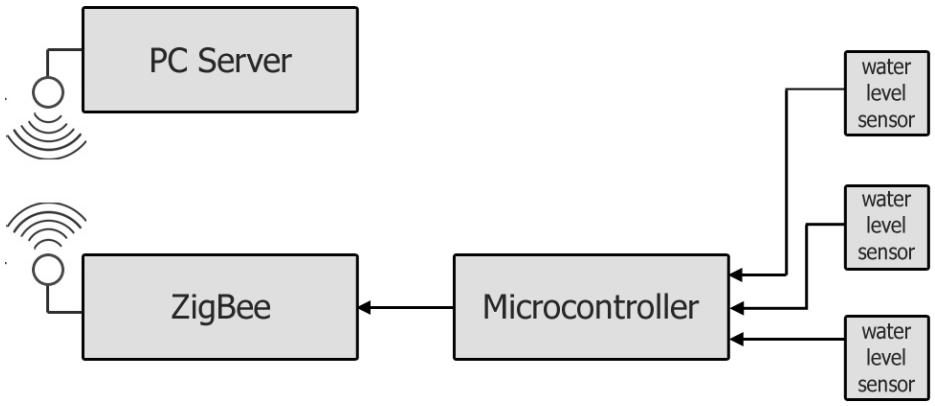

Figure 3.1 Block diagram of water level sensor

In Figure 3.1, the ZigBee will be programmed to act as a wireless personal network in which data will be sent to the main server wirelessly. The liquid level sensors will be programmed to monitor and to determine the water level condition inside the drainage. The liquid level sensors are positioned vertically to each other with certain distances - on the top, in the center, and below the acrylic container. They represent the water level condition in the drainage – high, medium, and low. Microcontroller will be used in order for the

ZigBee to interpret the data given by the liquid level sensors and to send it wirelessly from the water sensor to the PC server and vice-versa.

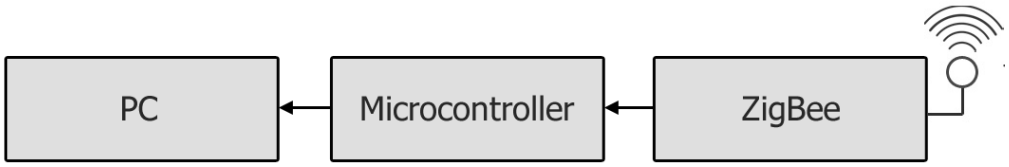

Figure 3.2 Block diagram of the PC server

Figure 3.2 shows the main server's ZigBee is programmed to be the network coordinator and to receive the data coming from the water level sensor. The microcontroller will be programmed to interpret the data coming from the ZigBee and to pass in to the main server. The server will have a program coded using Microsoft Visual Basic that is responsible for processing the data and displays it in its graphical user interface. Since the network is connected using mesh networking, only one ZigBee will be assigned as the coordinator and every other one will just have to transmit the data until it reaches it. While Figure 3.3 shows the schematic diagram of the components used in the system.

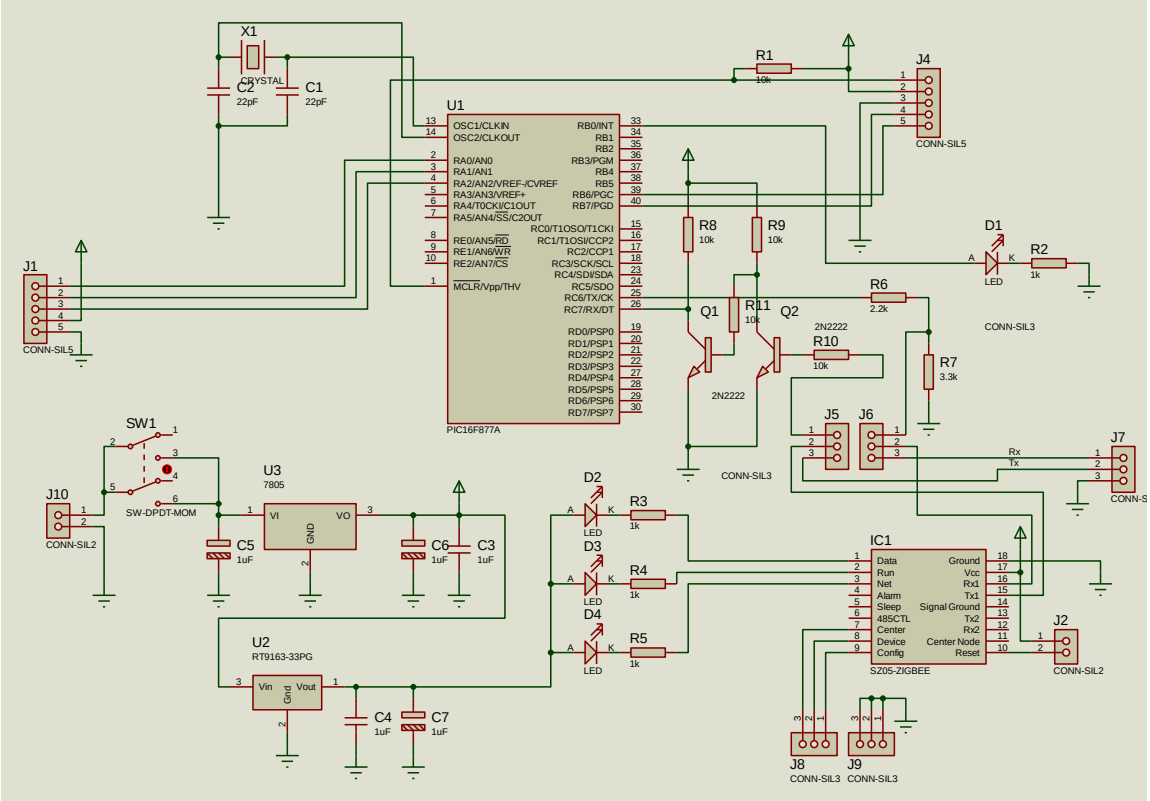

Figure 3.3 Schematic diagram

The schematic diagram has different parts in which the PIC 16F877A serves as the main part of the system. The PIC 16F877A is the microcontroller unit (MCU) where it controls the function of the system when sending data through the ZigBee. The J1 connector is where the water level sensor is placed in which it will send a string of numbers when it is activated. The transistor acts as a substitute to the crystal oscillator in which it increases the frequency/signal of the microcontroller. When the J10 connector (which is a switch) is triggered the circuit becomes operational. When the sensor is activated it will send a signal to the microcontroller, then sends a string data to the J4 connector which is the ZigBee. The ZigBee will then send that string data wirelessly.

The software will be coded using Microsoft Visual Basic. It will have a graphical user interface for controls and data output. Figure 3.4 illustrates the program flowchart.

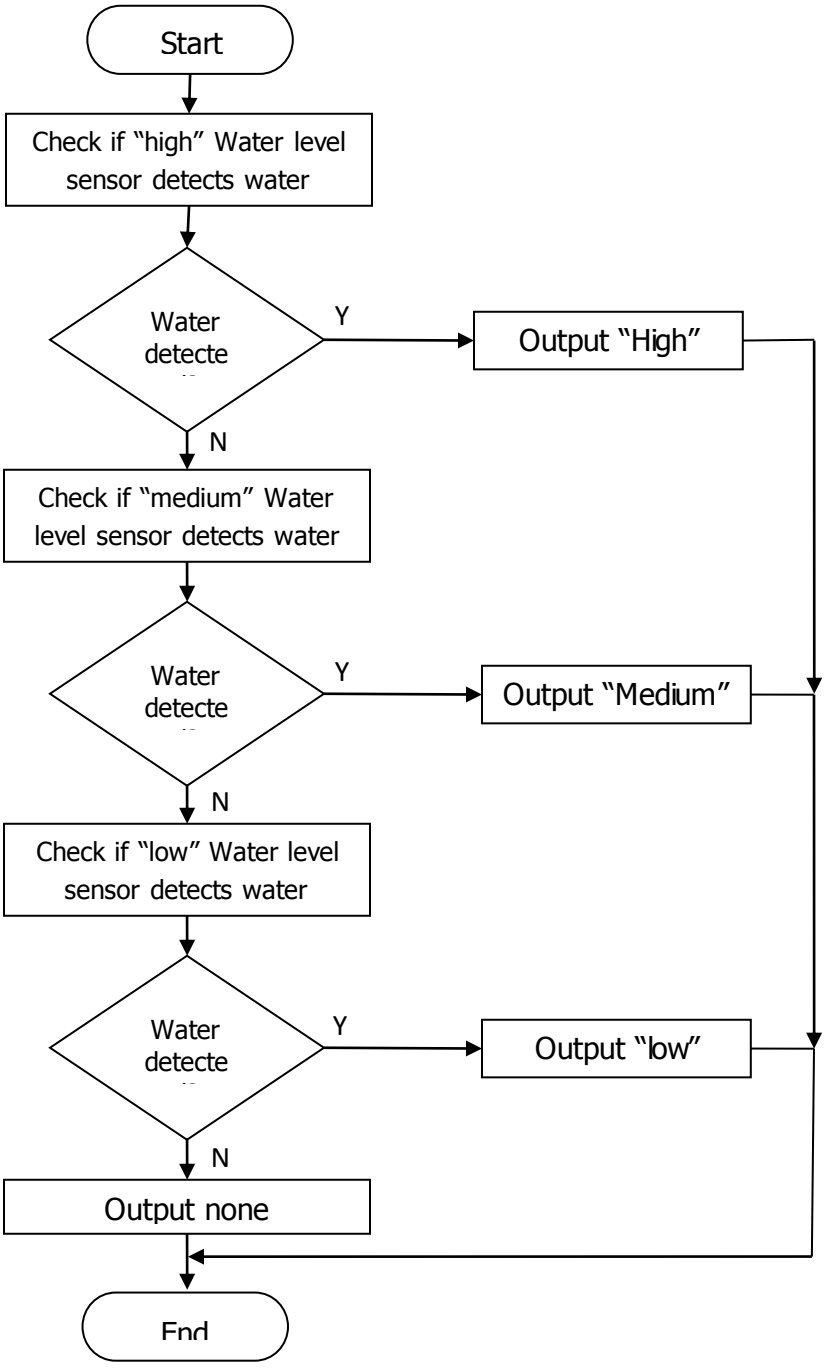

Figure 3.4 Program flowchart

The component that will represent the drainage tube is a container made in acrylic in which the liquid level sensors will be placed. The liquid level sensor returns only discrete values – "0"when it detects any kind of liquid substance and "1" otherwise. This returned data will then be processed by the PIC microcontroller unit. The liquid level sensors obtain its power source from the PIC microcontroller unit. The PIC microcontroller is then powered by an external power source. The ZigBee is used in creating a wireless personal network that allows data to be transmitted from one point to another until it reaches the ZigBee coordinator.

Chapter 4

TESTING, PRESENTATION, AND INTERPRETATION OF DATA

Sensor Accuracy Testing

The water level sensor has its own sets of conditions to work; it should be able to touch water for it to function. In this test, the sensor will be blocked by materials that affect the sensor's reading ability. Each test will have three sets of trials in which it will determine if the three sensors are able to function correctly despite the obstacle. The first test will have no barrier for the sensor; the water level should be filled enough to touch the three sensors and each of them should be able to detect the water. The procedure for the remaining tests will be the same as the first one. The only difference is each of the remaining tests has different barriers for the sensors. If a sensor is broken, it should output 'sensor error' instead of not outputting any result. Table 4.1 shows the results of the sensor accuracy testing.

Table 4.1 Sensor Accuracy Testing

		Sensor Reading		
Test	Barrier	LOW	MID	HIGH
1	No barrier	YES	YES	YES
2	Paper	YES	YES	YES
3	Bottle	NO	NO	NO
4	Plastic	NO	NO	NO

Based on the results, if there is no barrier the sensor is able to easily detect the water and no problems are encountered. The material is able to read the paper because the water can pass through the paper. Also the reading of the sensor depends on the thickness of the paper, when water can't pass through the paper there will no reading in the sensor. When there is a barrier like bottle, or plastic material, the sensor is not able to read anything. The reason is because the sensor needs to touch the water for it to have a reading. The sensor works when the water is touching it. The sensor is activated by the reflection of the water coming from its photo diode reading. So, any barrier facing the sensor will affect its reading or there will be no reading at all.

Signal Integrity Testing

ZigBee modules have different maximum range based on its manufacturer data sheet. This test will determine the maximum range of the ZigBee module having barriers and obstacles along its way. The tests to be conducted will be systematic where each will have three trials, and each having a different test condition. The first test is with no obstruction - the maximum range will be measured when there is no obstruction present. The following tests which will have obstructions will be tested and the maximum range will be determined. The obstructions to be tested for the system are glass, enclosed room, drawer, and door. Table 4.2 shows the result of the signal integrity testing.

Table 4.2 Signal Integrity Testing

		Maximum Range		
Test	Container	Trial 1	Trial 2	Trial 3
1	No obstruction	49M	52M	50M
2	Glass Panel	48M	46M	49M
3	Enclose Room	30M	27M	25M
4	Steel	25M	28M	26M
5	Door	29M	25M	27M

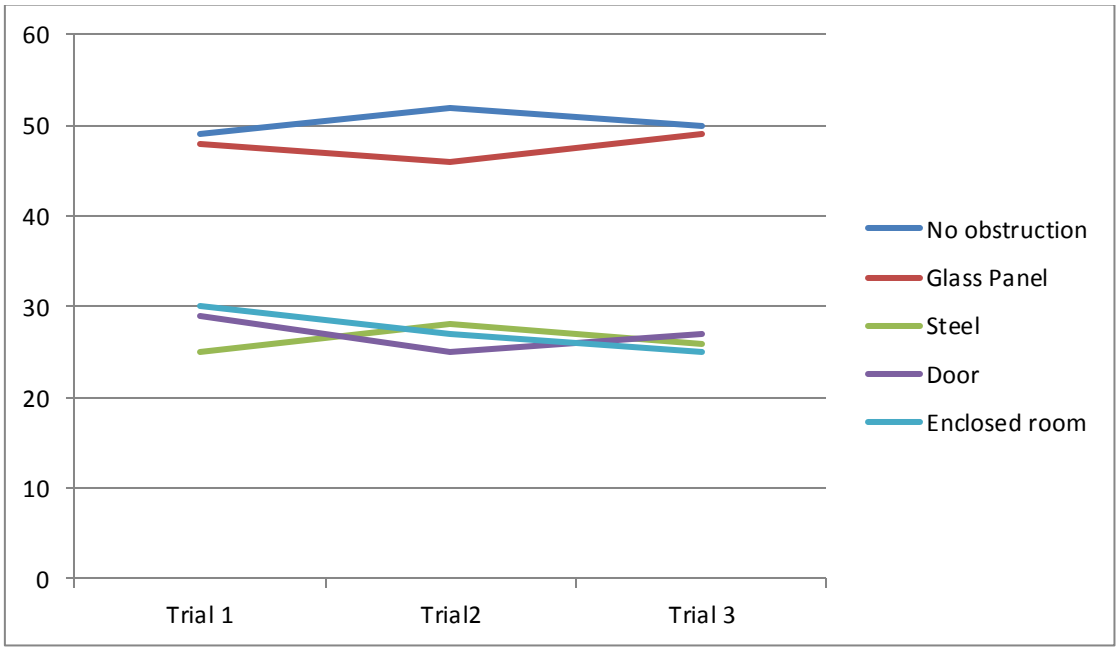

Figure 4.1 Graphical representation of the signal integrity test

Figure 4.1 illustrates the graphical representation of the signal integrity testing. The data is collected by measuring the maximum distance of the two ZigBee modules. The measurement is done manually using a measuring tape where this measures the end-to-end distance between the two modules. Based

on the results, the maximum range of the ZigBee can be achieved when there is no obstruction. For those with obstruction, the glass panel has the strongest range, meaning that the signal of the ZigBee can easily pass through the glass panel. The other obstructions have the same or close values because the signal is not able to pass through easily to those obstructions. The enclosed room have the weakest range because the ZigBee signal is greatly affected by the surrounding concrete and steel.

Chapter 5

CONCLUSION AND RECOMMENDATION

Conclusion

Monitoring drainage systems conditions remotely provide an easier, safe and efficient way of monitoring. In this design the researchers are able to present a wireless sensor network for monitoring of water level in the drainage systems using ZigBee. The system is capable of monitoring the water level in drainage systems remotely through the use of ZigBee. The designers approach in monitoring the drainage conditions is through the use of water level sensors which are read as low, middle, and high by the corresponding program done in VB.Net. Test simulations on the design show the effective range of the system to its remote server and the accuracy of reading of the sensors. The system implements the wireless network using ZigBee modules because of its efficiency and low power consumption.

Recommendation

It is recommended that additional study on how fast the water level increases and decreases from point A to point B. The flow of water should be determined using a flow sensor to determine how fast the flow of water is in the drainage pipe. The design should be a networked system where ZigBees and sensors are positioned and are placed in different drainages to improve monitoring of the water level in a drainage pipe. To improve the system, the use

of branch prediction will address the problem in determining how fast the water level increases and decreases. Also, an SMS notification maybe included in the system, to inform and to serve as warning to the public

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APPENDIX A

OPERATION'S MANUAL

1. System Requirements

The computer must meet these requirements to fully operate the system.

Operating System	Windows XP, Windows Vista, Windows 7
Processor	1.6 Ghz Pentium D
RAM	512 MB, 1GB of RAM recommended
Disk Space	80GB Hard Drive or more

2. Installation Procedure

Hardware

The hardware is composed of the liquid sensors and the wireless module. The liquid sensors are placed inside the drainage accordingly. The wireless module connected to them should be placed in a safe and secured place. It is recommended to minimize obstruction for the antenna signal and to put in a place away from the water.

The wireless modules should be at least 30 meters from each other. The central wireless module is attached to the PC server via the serial to USB cable. Each wireless module (except the central module) is supplied by a 9V battery.

Software

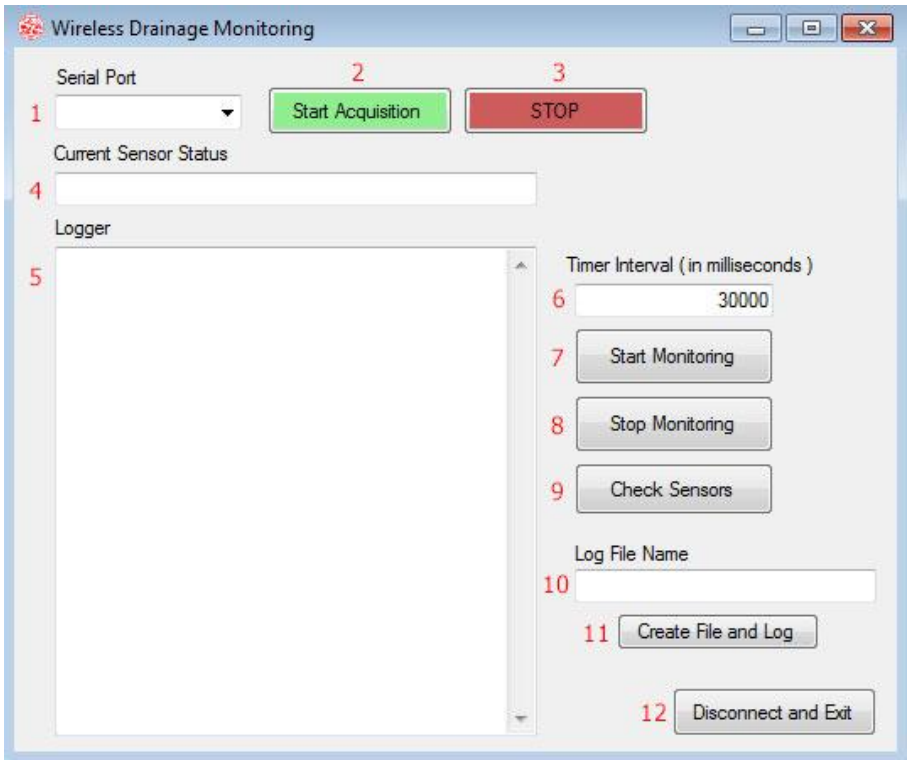
For the software, the entire files to be implemented are located in a single folder. The folder is to be placed in a desired location. It is recommended to place this folder in the "C:/Program Files" location.

3. User's Manual

Getting Started

1. Connect the Serial to USB cable to the wireless module and the PC server.
2. Start the software by executing the Wireless Drainage Monitoring application.
3. Press the "Start Acquisition" button to connect the wireless module and the PC server.
4. Press the "Start Monitoring" button to start the monitoring of water level. One can enter the desired time of interval for each level output in the "Time Interval" text box provided.
5. If a log file is desired to be created make sure to provide a name and press the "Create Log and File" before pressing the "Start Monitoring" button.
6. To stop the system from monitoring, press the "Stop Monitoring" button. To disconnect the PC from the wireless module, press the "STOP" button.
7. To check the status of the sensor, press the "Check Sensors" button. (Must stop the monitoring first)
8. To close the program, press "Disconnect and Exit".

User Interface



1. Serial Port Box – shows available ports to be used.
2. Start Acquisition Button – connects the wireless module and the PC server via the serial port selected.
3. STOP Button – stops the system from monitoring and disconnects the currently connected port.
4. Sensor Status – Outputs the current status of the sensor (i.e. low, medium, high).
5. Logger – displays and logs the output data of the liquid level sensors.
6. Time Interval – queries for the program and outputs the data from the liquid level sensors.

7. Start Monitoring Button – starts the monitoring of the water level of the program. The port and the PC must be connected first before one can start monitoring.
8. Stop Monitoring Button – stops the monitoring of the water level of the program.
9. Check Sensors Button – checks the current status of the water sensor; must stop monitoring first before you can check.
10. Log File Name – file name of the log file one wants to be created.
11. Create File and Log – creates the log file and starts logging the output data of the program into the log file.
12. Disconnect and Exit – disconnects the wireless module and PC server, then closes the program.

4. Troubleshooting Guides and Procedures

A. If start acquisition button returns and error, make sure first that the cable is properly connected, and have selected the available port.
B. If no log file is being recorded, make sure that one has selected the 'create file and log' button before selecting the 'start monitoring' button.
C. If there is no or an incorrect output, this may be because some of the wireless module cannot reach each other. One places the wireless module at least 50 meters from each other or nearer depending on how thick the obstruction is.

D. If there is still no or incorrect output, check the wireless module if they are still functioning or replace the battery.

Error Definitions

A. Connect to device first – device must be connected first via 'Start Acquisition' button before monitoring starts.
B. Port is closed – device must be connected first via 'Start Acquisition' button when this error appears.
C. Port already opened – error shows that the device is already connected when the user is trying to connect it.
D. Stop monitoring first – monitoring must first be disabled when this error appears.
E. No log file will be created – To enable a log file, one must create it first via the create log file button.

APPENDIX B

DATA SHEETS

PIC16F87XA

MICROCHIP

PIC16F87XA

28/40/44-Pin Enhanced Flash Microcontrollers

Devices Included in this Data Sheet:

- PIC16F873A
- PIC16F874A
- PIC16F876A
- PIC16F877A

High-Performance RISC CPU:

- Only 35 single-word instructions to learn
- All single-cycle instructions except for program branches, which are two-cycle
- Operating speed: DC – 20 MHz clock input
  DC – 200 ns instruction cycle
- Up to 8K x 14 words of Flash Program Memory, Up to 368 x 8 bytes of Data Memory (RAM), Up to 256 x 8 bytes of EEPROM Data Memory
- Pinout compatible to other 28-pin or 40/44-pin PIC16CXXX and PIC16FXXX microcontrollers

Peripheral Features:

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during Sleep via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. resolution is 12.5 ns
  - Compare is 16-bit, max. resolution is 200 ns
  - PWM max. resolution is 10-bit
- Synchronous Serial Port (SSP) with SPI™ (Master mode) and I^2C™ (Master/Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection
- Parallel Slave Port (PSP) – 8 bits wide with external $\overline{RD}$, $\overline{WR}$ and $\overline{CS}$ controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

Analog Features:

- 10-bit, up to 8-channel Analog-to-Digital Converter (A/D)
- Brown-out Reset (BOR)
- Analog Comparator module with:
  - Two analog comparators
  - Programmable on-chip voltage reference (V_{REF}) module
  - Programmable input multiplexing from device inputs and internal voltage reference
  - Comparator outputs are externally accessible

Special Microcontroller Features:

- 100,000 erase/write cycle Enhanced Flash program memory typical
- 1,000,000 erase/write cycle Data EEPROM memory typical
- Data EEPROM Retention > 40 years
- Self-reprogrammable under software control
- In-Circuit Serial Programming™ (ICSP™) via two pins
- Single-supply 5V In-Circuit Serial Programming
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving Sleep mode
- Selectable oscillator options
- In-Circuit Debug (ICD) via two pins

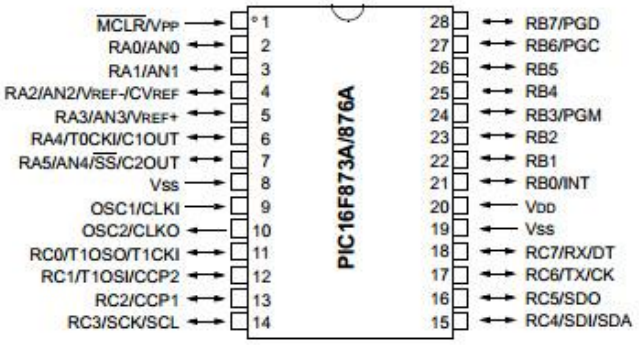
CMOS Technology:

- Low-power, high-speed Flash/EEPROM technology
- Fully static design
- Wide operating voltage range (2.0V to 5.5V)
- Commercial and Industrial temperature ranges
- Low-power consumption

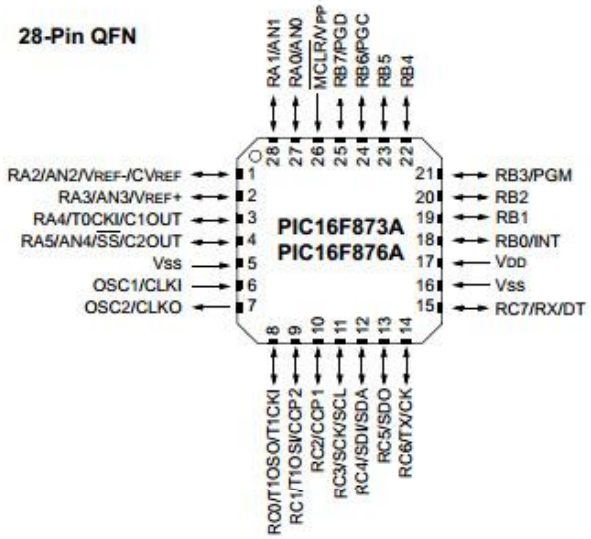
Device	Program Memory		Data SRAM (Bytes)	EEPROM (Bytes)	I/O	10-bit A/D (ch)	CCP (PWM)	MSSP		USART	Timers 8/16-bit	Comparators
	Bytes	# Single Word Instructions						SPI	Master I^2C			
PIC16F873A	7.2K	4096	192	128	22	5	2	Yes	Yes	Yes	2/1	2
PIC16F874A	7.2K	4096	192	128	33	8	2	Yes	Yes	Yes	2/1	2
PIC16F876A	14.3K	8192	368	256	22	5	2	Yes	Yes	Yes	2/1	2
PIC16F877A	14.3K	8192	368	256	33	8	2	Yes	Yes	Yes	2/1	2

Pin Diagrams

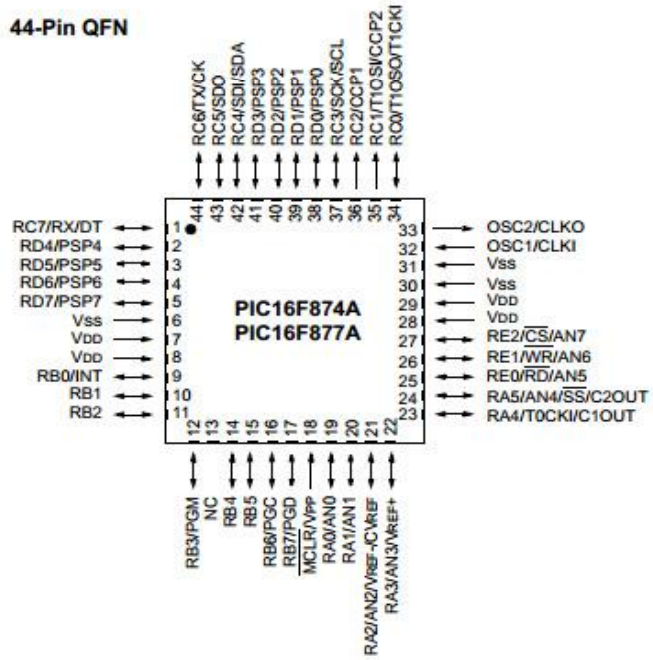
28-Pin PDIP, SOIC, SSOP



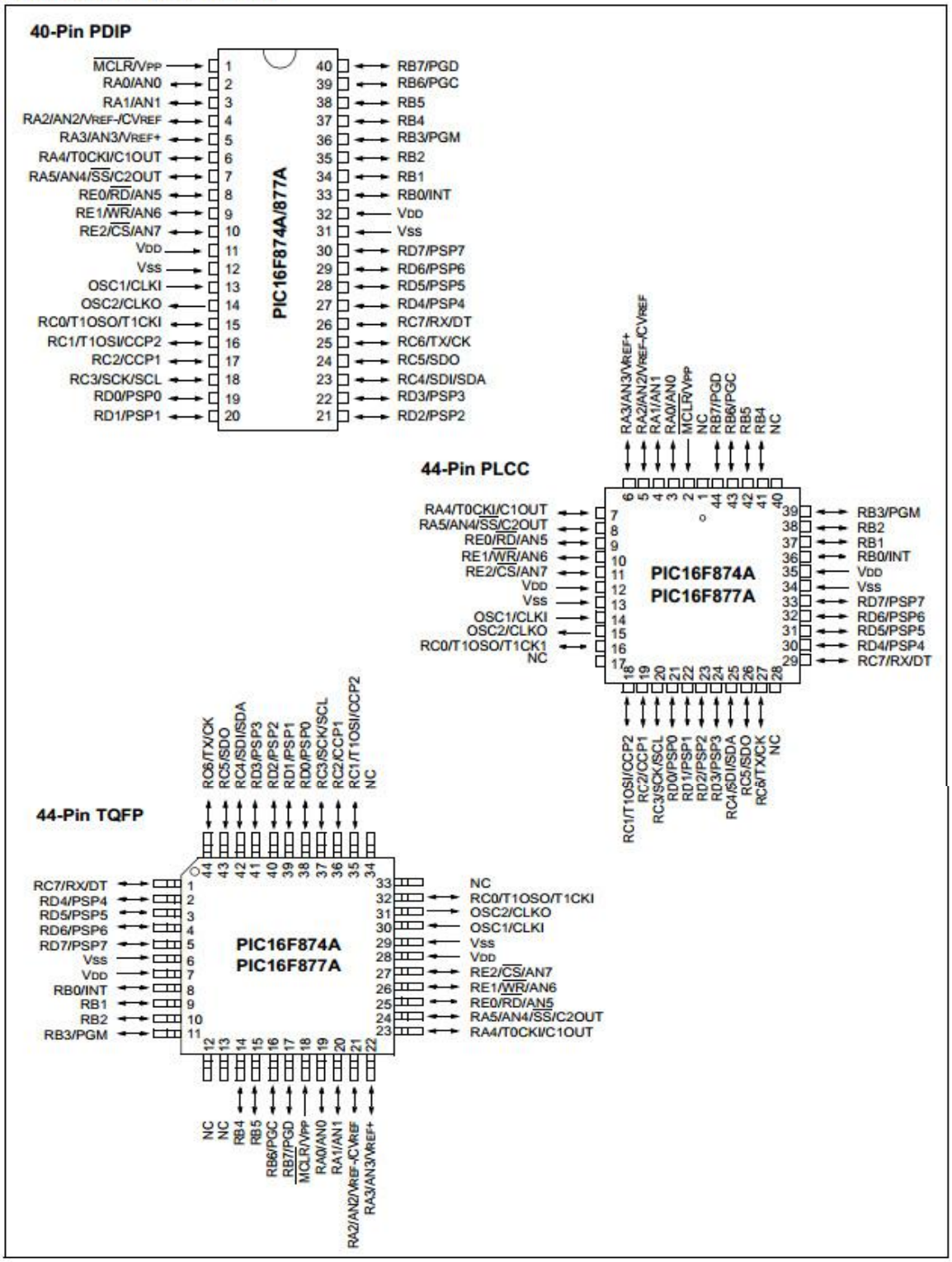
28-Pin QFN



44-Pin QFN



Pin Diagrams (Continued)



SZ05-ZIGBEE

I Introduction

The boat SZ05 series of embedded wireless communication module integrated ZigBee protocol standards radio frequency transceivers and microprocessors. It has the characteristics and advantages of long communication distance, strong anti-jamming capability, flexible network and stable performance. Meanwhile, it can achieve point-to-point, multipoint, multi-multipoint transparent data transfer between devices. And the devices communicate with each other forms the network of a star, a branching tree or a net (mesh).

SZ05 series of wireless communication module's data interfaces including: TTL interface and RS232 standard interface. They can send the data by way of broadcast or target address. In addition to achieving the general point-to-point data communication functions, they also can realize the multipoint communication. What's more, the serial communication is so easy and convenient to use that it can reduce the matching process time of inserting the embedded module.

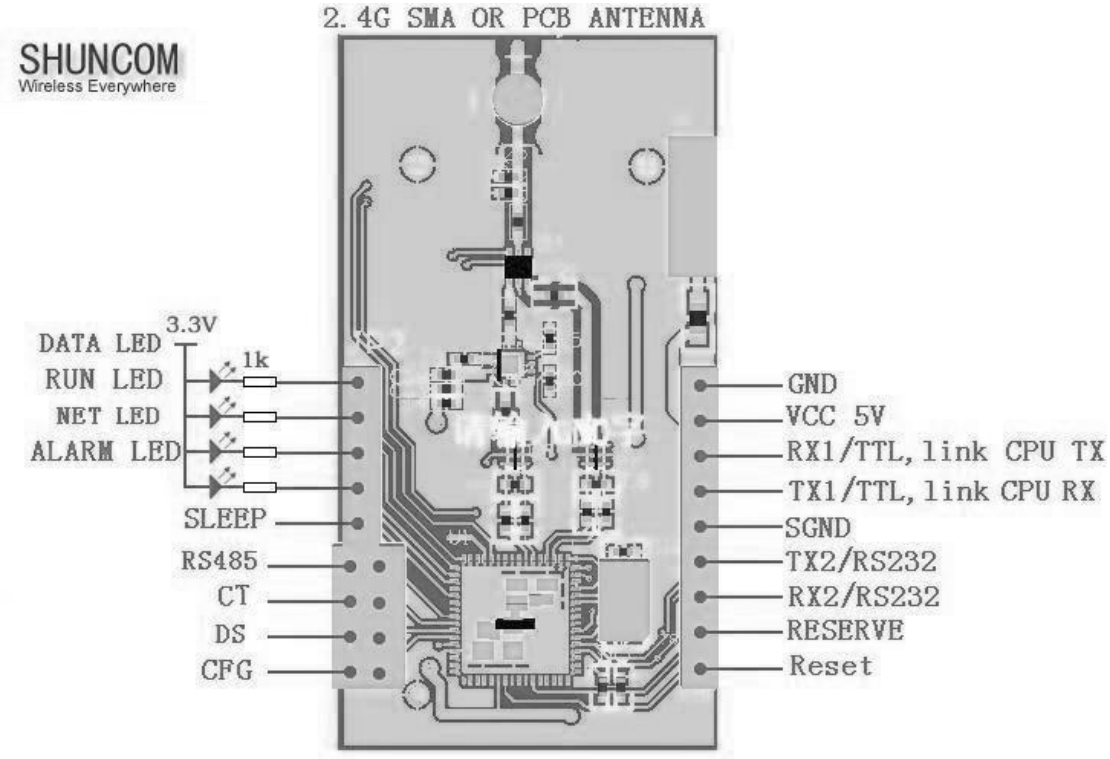
SZ05 series of wireless communication module is divided into three nodes in the network: Central Coordinator, Router and End-Device. They have different functions in the network. The Central Coordinator is the central nodes which can automatically initiate maintain and manage the information of the network. The Router takes the charge of liking network together, transmitting the data and associating with other routers and End-devices. And the terminal nodes only send and receive the data. Central coordinator, a router and terminal node, these three types of devices are the same in hardware but the embedded software is different. In way of jumpers settings or software configuration can realize the different functions of devices.

II Technical specifications

Category	Index name	SZ05 series wireless module
Wireless network	The transmission distance	100 meters - 2,000 meters
	Network topology	Star, tree and chain type, mesh network
	Addressing mode	IEEE802.15.4 / ZIGBEE standard address
	Network ID	255
Data interface	Maximum data packet	256 bytes
	Data interface	TTL , RS232 standard interface
	Serial signal	TxD, RxD, GND

	Serial rate	1,200 ~ 38,400 bps
	Serial calibration	None, Even, Odd
	Data bits,	7, 8
	parity	1
transceiver	Modulation mode	The DSSS direct sequence spread spectrum
	Frequency range	2.405GHz~ 2.480GHz
	Wireless channel	16
	Receiving sensitivity	-94 dbm
	Transmission power	-27dBm~25dBm
	Antenna	The outer SMA antenna or PCB antenna
	Conflict prevention	GTS CSMA - CA and CSMA - CA
power	Input voltage	DC 5V
	Maximum current	70 mA
	Maximum receiving current	55 mA
	Standby current	10 mA
	Power saving mode	110 uA
	Sleep pattern	30 uA
Working environment	Working temperature	-40℃ ~ 85℃
	Storage temperature	-55℃ ~ 125℃

III Interface



SZ05 series embedded module typical wiring diagram

3.1 Module to the left of pin identification

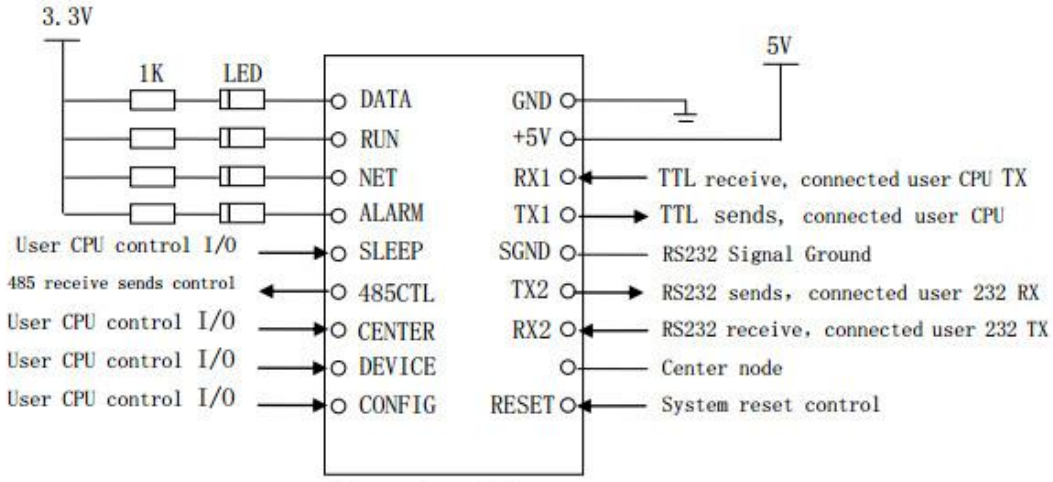
Sequence	Mark	Function	Notes
1	GND	Ground	
2	+5V	Power input is 5V	
3	RX1/TTL	TTL level input	TX output to connect the user system
4	TX1/TTL	TTL level output	RX input to connect the user system
5	SGND	Serial RS232 signal ground	Ground
6	TX2/RS232	Serial RS232 output	Connect the user input 232
7	RX2/RS232	Serial RS232 input	Connect the user output 232

8		System reserved	Vacant
9	RESET	System reset	LOW Reset

3.2 Module to the right of pin identification

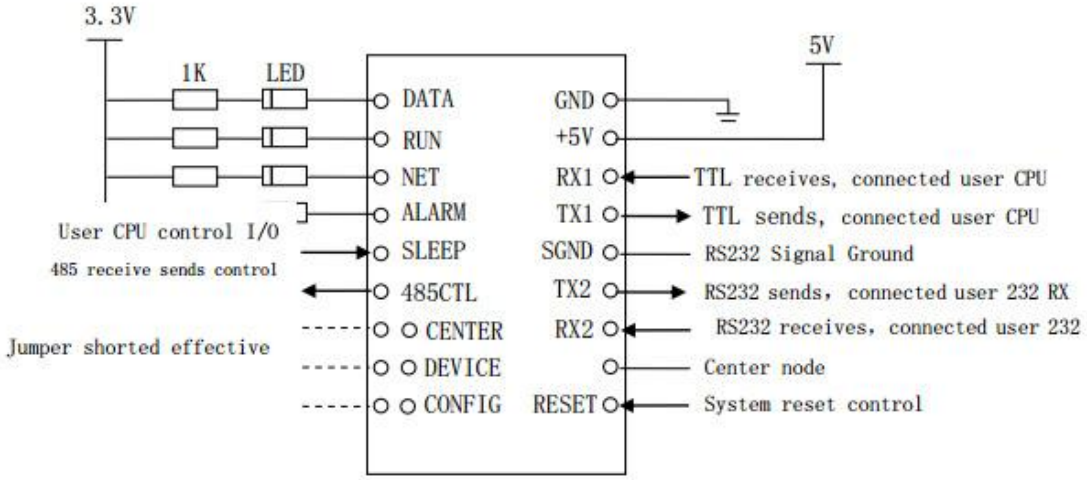
Sequence	Mark	Function	Notes
1	DATA	Sending and receiving data instructions	Low light. the data transceiver is flashing
2	RUN	System running light	Low light. interval of 1second flashes
3	NET	Network indicators	Low light. the center succeeded in building a network node, bright light from the node to connect the network
4	ALARM	System warning light	Low light
5	SLEEP	Low power consumption	Low access to low-power, high level or normal operation of floating
6	485CTL	485 transceiver control	Low output when the module 485 to receive. high output when it sent
7	CENTER	Center node	Low effective or adding the jumper cap becomes a central node. If 7 and 8 are as high level or floating it is the routing node.
8	DEVICE	Terminal node	Low effective or adding the jumper cap into the terminal nodes. If 7 and 8 are as high or floating it is the routing node
9	CONFIG	Configuration interface	Low effective or adding the jumper cap into the system configuration state

3.3 Module wiring diagram



User system wiring one

Wiring One: CPU control of the user system I / O port to control the function of all modules



User system wiring two

Wiring Two: A short jumper connection to control the center node, relay routing node or the terminal node is set into CONFIG mode, if the short jumper was effective, central node or terminal node jumper selection can only be chosen one. If both of them are suspended, the node will be a relay routing node. The suspended state comes into work if CONFIG is set into the configuration state by a short jumper.

3.4 Module control lines

Pin	Module initialization	Valid state	User Control I / O initialization	Control state
DATA	High level 3.3V	Low level	——	——
NET	High level 3.3V	Low level	——	——
RUN	High level 3.3V	Low level	——	——
ALARM	High level 3.3V	Low level	——	——
SLEEP	High level 3.3V	——	High level 3.3V	Low level
485CTL	Low level	——	Connect the 485 chips controller	——
CENTER	High level 3.3V	Low level	High level 3.3V	Low level
DEVICE	High level 3.3V	Low level	High level 3.3V	Low level
CONFIG	High level 3.3V	Low level	High level 3.3V	Low level 3 seconds
RESET	High level 3.3V	Low level	High level 3.3V	Low level

3.5 Power Interface

The standard operating voltage of SZ05-ZBEE wireless communication module is DC-5V. The normal operating voltage range is from5V to 12V.

Notes: The power of positive and negative can not be reversed. Otherwise they will burn out the module.

3.6 Data interface

SZ05-ZBEE wireless communication module offers two standard interfaces: RS232 interface and TTL interface. The working interfaces of serial port RS232 are TX, RX and GND. However, the TTL working interfaces are TX and RX. And the TTL level is 3.3V.

Serial port parameters	Default Set
Serial Rate	9,600

Serial check	None
Data bits	8
Stop bit	1

3.7 Node type configuration

SZ05-ZBEE wireless communication module has three node types: center node, relay routing node and the terminal node. A short jumper connection is to control the center node, the relay routing node or the terminal node, if the short jumper is effective, the center node or the terminal node can be only chosen one. This node will be the relay routing node if the two short jumpers are suspended.

3.8 Configuration interface

If CONFIG jumper shorted or external control line of SZ05-ZBEE wireless communication module gets into the low level state in 3 seconds, the system will come into the configuration state. Being high level or floating is the working state. Configuration interface is used for some parameters to be configured. The default configuration of Serial RS232 is as follows:

Serial port parameters	Default Set
Serial Rate	38,400
Serial check	None
Data bits	8
Stop bit	1

Configuration interface settings

The configuration mode of SZ05-ZBEE wireless communication module can be divided into super-terminal configuration mode and the computer network management configuration mode. The state of the two models is classified as follows:

Instructions state	Instructions meaning
Super- terminal configuration mode	Data, operation, network and alarm light flicker at the same time
Computer network management configuration mode	Alarm light flashes in 1 second interval. Running lights flashes normally. Data light don't flicker.

Super- terminal configuration mode means entering the computer's super terminal to do the module settings.

Computer network management configuration model is the protocol specification which can provide the system interface for the user to carry on the software integration.

The steps of the Super-terminal configuration mode

1. Open the computer's HyperTerminal and set HyperTerminal as follows: 38400 baud, 8 data bits, check NONE, stop bits 1, flow control none.
2. CONFIG jumper shorted or external control line comes into the low level.
3. Power to devices.
4. Entering the device configuration mode.

Notes: Being the configuration mode, the serial port is configured: 38400 baud, 8 data bits, check NONE, stop bit 1. So the computer's serial port settings must be 38400 baud, 8 data bits, check NONE, stop bit 1, flow control NONE.

IV Module configuration

Equipment configuration options are as follows :

Configuration options	Chinese options	Configuration	The default parameters
CHANNEL	A communication channel	Use Netcom channel	0x0F
NET_TYPE	Network type		Mesh network
NODE_TYPE	Device type		Relay route
NET_ID	Network ID	Use Netcom number	0xFF
TX_TYPE	Sending mode		radio
MAC_ADDR	Device address	Different device has different address	——
DATA_TYPE	Data type		HEX

DATA_BIT	Data bits,		8
BAUD_RATE	Baud rate		9,600
PARITY	Data validation		NONE
TIME_OUT	Serial overtime		0x05 ms
SRC_ADDR	Data source address		Not output

4.1 Communication channel set

Channel	Configuration instructions	Notes
0-F	0 : 2.405GHz 1 : 2.410GHz 2 : 2.415GHz 3 : 2.420GHz 4 : 2.425GHz 5 : 2.430GHz 6 : 2.435GHz 7 : 2.440GHz 8 : 2.445GHz 9 : 2.450GHz A : 2.455GHz B : 2.460GHz C : 2.465GHz D : 2.470GHz E : 2.475GHz F : 2.480GHz	Recommended 4, 9, 14 or 15 channels, which can avoid WIFI interference.
G	AUTO mode to choose the best channel	

4.2 NET_TYPE network type

NET_TYPE options	Network type	Configuration	notes
MESH	Mesh network	Master-slave network and the network must have only one center node.	In the same network, the network type must be set the same.
STAR	Star nets		

LINE_1	Chain type nets ID=1		
LINE_2	Chain type nets ID=2		
LINE_3	Chain type nets ID=3		
LINE_4	Chain type nets ID=4		
PEER	Peer-to-peer network	Master-slave network No center node	

4.3 NODE_TYPE device type

NODE_TYPE options	Network types	Configuration	note
PAN_COORD	Center node		There must be a center node in the network.
ROUTER	Relay route	It has the terminal equipment functions, too.	
END_DEVICE	Terminal equipment		

SZ05-ZBEE wireless communication module has three types: the center node, the relay routing node and the terminal node. A short jumper connection is to control the center node, the relay routing node or the terminal node, if the short jumper connection is effective, the center node or the terminal node can be only chosen one. This node will be the relay routing node if the two short jumpers are suspended.

4.4 The network number NET_ID Settings

NODE_TYPE options	ID range	Configuration	notes
NET_ID	00—FF	The whole network's ID must be the same.	

In a network, ENTER NET_ID # 2, then click "setup". ENTER the ENTER

4.5 Data sent TX_TYPE mode Settings

TX_TYPE options	Send mode	Configuration	notes

BROADCAST	Broadcast mode	No target address	If target address is 2 bytes MAC address, it must be added before the packet.
MASTER—SLAVE	Master-slave mode	The center node must have target address. Non-central nodes haven't target address and default send the data to the center node.	
POINT—POINT	peer-to-peer	Target address must	

4.6 Equipment MAC_ADDR address

MAC_ADDR options	ID range	Configuration	note
MAC_ADDR	0000—FFFE	The address of center node is 0000	The whole network cannot have the same address nodes.

Input the net 4 device address and then press "ENTER" to finish the setup.

4.7 DATA_TYPE data types

DATA_TYPE options	Data types	Configuration
ASCII	ASCII	It must be set if has the target address. If broadcast way without settings.
HEX	Hex	

4.8 DATA_BIT set

DATA_TYPE options	Data types	Configuration
7+1+1	7 bit data + 1 check + 1 stop bits	To combine with data validation to set
8+0+1	8 bit data +0 check + 1 stop bits	

8+1+1	8 bit data +1 check + 1 stop bits	

4.9 Serial BAUD_RATE set

BAUD_RATE options	Baud rate range	Configuration
1,200	1,200-3,8400	Choose match baud rate
38,400		

4.10 DATA_PARITY set

DATA_PARITY options	Equipment types	Configuration
NONE	No calibration	Select the match calibration type
EVEN	Parity checking	
ODD	Parity checking	

4.11 Serial TIME_OUT set

TIME_OUT options	Equipment types	notes
TIME_OUT	1-255ms（Hexadecimal display）	Serial overtime time.

4.12 SRC_ADDR data source address set

SRC_ADR options	Data source address	Configuration
NOT OUTPUT	Not output source address	According to the application to choose whether to output source address of data packets
HEX	Hexadecimal output	

ASCII	ASCII output	

The formats of Hexadecimal output source address: 2 bytes of data source address + valid data. The formats of ASCII mode output source address: 4 bytes of data source address +valid data.

V Data sending instructions

5.1 Data sending mode

Module type	Send mode	Goal node	Send mode
Center node	radio	All non-central node within the network	Data directly
	Master-slave or peer-to-peer	Target address node	Target address + data
Non-central node	radio	All non-central node	Data directly
	Master-slave	Center node	Data directly
	peer-to-peer	Target address node	Target address + data

5.2 Data transmission frame format

Send mode	Data coding	Data frame format
Data directly		Do not make any changes
Target address + data	Hexadecimal target address	2 bytes target address + data
	ASCII target address	4 bytes target address + data

Honeywell
MICRO SWITCH

Solid state liquid level sensors

General Information

The LL series liquid level sensor provides a single point detection via a TTL/CMOS compatible output. When liquid is present on the surface of sensor the output sinks up to a maximum of 40mA.

LED and optoschmitt chips are sealed into the base of a clear plastic dome, in such a position that light is normally totally internally reflected from the dome boundary to the optoschmitt. Thus the output is normally high. When liquid covers the dome, the change in refractive index at the boundary means light escapes into the liquid, less light reaches the optoschmitt which thus turns off.

Cleaning

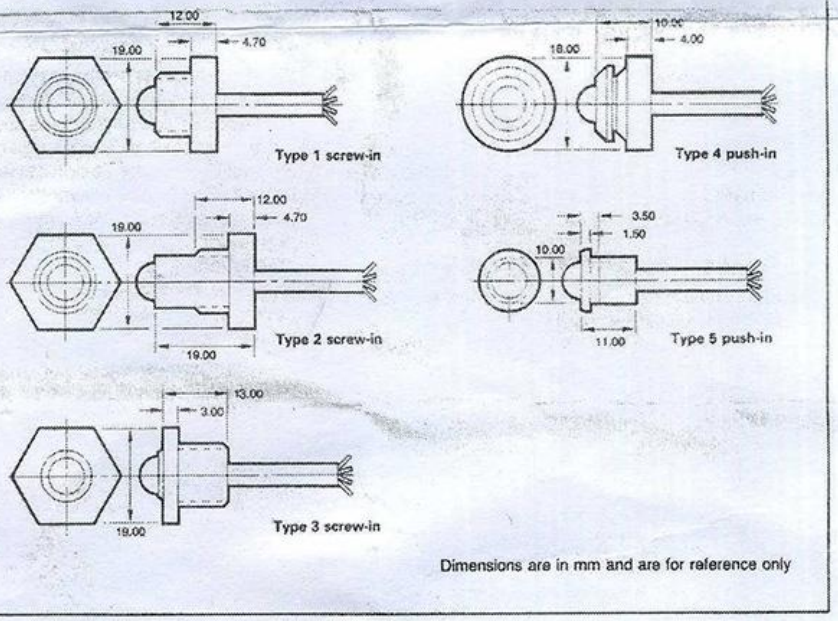
Proper fluids should be selected based on type of contaminant to be removed. Honeywell recommends freon and alcohol based solvents.

Do not use chlorinated solvents such as trichlorethane as these are likely to attack the sensor material.

CAUTION

- Do not exceed maximum supply voltage.
- Do not reverse supply.
- Do not connect LED wire (black) direct to supply voltage.
- Do not overtighten screw in types.
- Do not use chlorinated solvents.
- Do not mount with dome pointing down.

Mounting dimensions



Dimensions are in mm and are for reference only

APPENDIX C

PROGRAM LISTING

Microcontroller Program

```
#define MX_PIC
#define MX_USES_UINT8 1
#define MX_USES_SINT16 0
#define MX_USES_CHAR 0
#define MX_USES_FLOAT 0
#define MX_USES_SINT32 0
#define MX_USES_BOOL 1
#define MX_USES_UINT16 0
#define MX_USES_UINT32 0
//Defines for microcontroller
#define P16F877A
#define FC_CAL_PIC
#define MX_ADC
#define MX_ADC_TYPE_1
#define MX_ADC_BITS_10
#define MX_EE
#define MX_EE_TYPE2
#define MX_EE_SIZE 256
#define MX_SPI_1
#define MX_SPI_1_MISO_PORT
portc
#define MX_SPI_1_MISO_TRIS trisc
#define MX_SPI_1_MISO_PIN 4
#define MX_SPI_1_MOSI_PORT
portc
#define MX_SPI_1_MOSI_TRIS trisc
#define MX_SPI_1_MOSI_PIN 5
#define MX_SPI_1_CLK_PORT portc
#define MX_SPI_1_CLK_TRIS trisc
#define MX_SPI_1_CLK_PIN 3
#define MX_SPI_1_SS_PORT portc
#define MX_SPI_1_SS_TRIS trisc
#define MX_UART_1
#define MX_UART_1_TX_PORT portc
#define MX_UART_1_TX_TRIS trisc
#define MX_UART_1_TX_PIN 6
#define MX_UART_1_RX_PORT
portc
#define MX_UART_1_RX_TRIS trisc
#define MX_UART_1_RX_PIN 7
#define MX_I2C
#define MX_MI2C
#define MX_I2C_1
#define MX_I2C_1_SDA_PORT portc
#define MX_I2C_1_SDA_TRIS trisc
#define MX_I2C_1_SDA_PIN 4
#define MX_I2C_1_SCL_PORT portc
#define MX_I2C_1_SCL_TRIS trisc
#define MX_I2C_1_SCL_PIN 3
#define MX_PWM
#define MX_PWM_CNT 2
#define MX_PWM_PSCA1
#define MX_PWM_PSCA4
#define MX_PWM_PSCA16
#define MX_PWM_1_PORT portc
#define MX_PWM_1_TRIS trisc
#define MX_PWM_1_PIN 2
#define MX_PWM_2_PORT portc
#define MX_PWM_2_TRIS trisc
#define MX_PWM_2_PIN 1

//Functions
#define MX_CLK_SPEED 20000000
#ifdef _BOOSTC
#include <system.h>
#endif
#ifdef HI_TECH_C
#include <pic.h>
#endif

//Configuration data
#ifdef _BOOSTC
#pragma DATA 0x2007, 0x3f3a
#endif
#ifdef HI_TECH_C
```

```
__CONFIG(0x3f3a);
#endif

//Internal functions
#include "D:\Program
Files\Flowcode\v5\FCD\internals.c"

//Macro function declarations

//Variable declarations
#define FCV_FALSE (0)
#define FCV_TRUE (1)
MX_UINT8 FCV_SERIAL_IN;
MX_UINT8 FCV_LEVELSENSORS;

//RS232(0): //Defines:

/**** Macro Substitutions ****
a = Unique Reference
b = Uart Channel (0-software / 1-4
hardware)
c = tx pin
d = tx port
e = rx pin
f = rx port
g = flow control (0-Off / 1-On)
h = cts pin
i = cts port
j = rts pin
k = rts port
l = baud rate
m = data bits (7/8/9) (7 only
supported in software modes)
n = return type (0-byte / 1-
MX_UINT16)
o = echo enable (0-Off / 1-On)
//Definitions for RS232 UART slot
allocation
#ifndef MX_UART_REF1
#define MX_UART_REF1
#define RS232_1_MX_UART_UREF 1
#define MX_UART_CHANNEL_1 1
#define MX_UART_TX_PIN_1 0
#define MX_UART_TX_PORT_1
porta
#define MX_UART_TX_TRIS_1 trisa
#define MX_UART_RX_PIN_1 0
#define MX_UART_RX_PORT_1
porta
#define MX_UART_RX_TRIS_1 trisa
#define MX_UART_FLOWEN_1    0
#define MX_UART_CTS_PIN_1    4
#define MX_UART_CTS_PORT_1
portc
#define MX_UART_CTS_TRIS_1 trisc
#define MX_UART_RTS_PIN_1    0
#define MX_UART_RTS_PORT_1
portc
#define MX_UART_RTS_TRIS_1 trisc
#define MX_UART_BAUD_1 9600
#define MX_UART_DBITS_1 8
#define MX_UART_RETURN_1 0
#define MX_UART_ECHO_1 0
#define MX_UART_INT_1  0
#else
#ifndef MX_UART_REF2
#define MX_UART_REF2
#define RS232_1_MX_UART_UREF 2
#define MX_UART_CHANNEL_2 1
#define MX_UART_TX_PIN_2 0
#define MX_UART_TX_PORT_2
porta
#define MX_UART_TX_TRIS_2 trisa
#define MX_UART_RX_PIN_2 0
#define MX_UART_RX_PORT_2
porta
#define MX_UART_RX_TRIS_2 trisa
#define MX_UART_FLOWEN_2 0
```

```
#define MX_UART_CTS_PIN_2 4
#define MX_UART_CTS_PORT_2
portc
#define MX_UART_CTS_TRIS_2 trisc
#define MX_UART_RTS_PIN_2 0
#define MX_UART_RTS_PORT_2
portc
#define MX_UART_RTS_TRIS_2 trisc
#define MX_UART_BAUD_2 9600
#define MX_UART_DBITS_2 8
#define MX_UART_RETURN_2 0
#define MX_UART_ECHO_2 0
#define MX_UART_INT_2  0
#else
#ifndef MX_UART_REF3
#define MX_UART_REF3
#define RS232_1_MX_UART_UREF 3
#define MX_UART_CHANNEL_3 1
#define MX_UART_TX_PIN_3 0
#define MX_UART_TX_PORT_3
porta
#define MX_UART_TX_TRIS_3 trisa
#define MX_UART_RX_PIN_3 0
#define MX_UART_RX_PORT_3
porta
#define MX_UART_RX_TRIS_3 trisa
#define MX_UART_FLOWEN_3 0
#define MX_UART_CTS_PIN_3 4
#define MX_UART_CTS_PORT_3
portc
#define MX_UART_CTS_TRIS_3 trisc
#define MX_UART_RTS_PIN_3 0
#define MX_UART_RTS_PORT_3
portc
#define MX_UART_RTS_TRIS_3 trisc
#define MX_UART_BAUD_3 9600
#define MX_UART_DBITS_3 8
#define MX_UART_RETURN_3 0
#define MX_UART_ECHO_3 0
#define MX_UART_INT_3  0
#else
#ifndef MX_UART_REF4
#define MX_UART_REF4
#define RS232_1_MX_UART_UREF 4
#define MX_UART_CHANNEL_4 1
#define MX_UART_TX_PIN_4 0
#define MX_UART_TX_PORT_4
porta
#define MX_UART_TX_TRIS_4 trisa
#define MX_UART_RX_PIN_4 0
#define MX_UART_RX_PORT_4
porta
#define MX_UART_RX_TRIS_4 trisa
#define MX_UART_FLOWEN_4 0
#define MX_UART_CTS_PIN_4 4
#define MX_UART_CTS_PORT_4
portc
#define MX_UART_CTS_TRIS_4 trisc
#define MX_UART_RTS_PIN_4 0
#define MX_UART_RTS_PORT_4
portc
#define MX_UART_RTS_TRIS_4 trisc
#define MX_UART_BAUD_4 9600
#define MX_UART_DBITS_4 8
#define MX_UART_RETURN_4 0
#define MX_UART_ECHO_4 0
#define MX_UART_INT_4  0
  #endif
#endif
 #endif
#endif

#define RS232_1_UART_Init
CAL_APPEND(FC_CAL_UART_Init_,
RS232_1_MX_UART_UREF)
#define RS232_1_UART_Send
CAL_APPEND(FC_CAL_UART_Send_,
RS232_1_MX_UART_UREF)
```

```
#define RS232_1_UART_Receive
CAL_APPEND(FC_CAL_UART_Receiv
e_, RS232_1_MX_UART_UREF)
#define
RS232_1_UART_Update_Baud
CAL_APPEND(FC_CAL_UART_Update
_Baud_, RS232_1_MX_UART_UREF)

extern void RS232_1_UART_Init();
extern void
RS232_1_UART_Send(MX_UINT16
nChar);
extern MX_SINT16
RS232_1_UART_Receive(MX_UINT8
nTimeout);
extern void
RS232_1_UART_Update_Baud(MX_U
INT8 newbaud);

//RS232(0): //Macro function
declarations

void
FCD_RS2320_SendRS232Char(MX_S
INT16 nChar);
void
FCD_RS2320_SendRS232String(MX_
STRING String, MX_UINT8
MSZ_String);
MX_SINT16
FCD_RS2320_ReceiveRS232Char(MX
_UINT8 nTimeout);
void
FCD_RS2320_ReceiveRS232String(M
X_CHAR* FCR_RETVAL, MX_UINT8
FCR_RETVAL_SIZE, MX_UINT8
nTimeout, MX_UINT8 NumBytes);

void
FCD_RS2320_ChangeHWBaud(MX_U
INT8 newbaud);



//RS232(0): //Macro
implementations


void
FCD_RS2320_SendRS232Char(MX_S
INT16 nChar)
{

                RS232_1_UART_Send (
nChar);

}

void
FCD_RS2320_SendRS232String(MX_
STRING String, MX_UINT8
MSZ_String)
{
         MX_UINT8 idx;
         for(idx = 0; idx <
MSZ_String; idx++)
                {
        if (String[idx] == 0)
        break;
        else RS232_1_UART_Send (
String[idx] );
                }
}

MX_SINT16
FCD_RS2320_ReceiveRS232Char(MX
_UINT8 nTimeout)
```

```
{
return ( RS232_1_UART_Receive (
nTimeout) );
}

void
FCD_RS2320_ReceiveRS232String(M
X_CHAR* FCR_RETVAL, MX_UINT8
FCR_RETVAL_SIZE, MX_UINT8
nTimeout, MX_UINT8 NumBytes)
{
        MX_UINT8 idx;
        MX_SINT16 RS232_TO = 255;
                MX_SINT16 in;

        if ( 0 != 0 )
                        RS232_TO =
256;

        if (NumBytes >
FCR_RETVAL_SIZE)
                        NumBytes =
FCR_RETVAL_SIZE;

        for (idx = 0; idx < NumBytes;
idx++)
                {
        in = RS232_1_UART_Receive
( nTimeout);
        if(in < RS232_TO)

        FCR_RETVAL[idx] = in &
0xFF;
        else
                break;
        }

        if (idx < FCR_RETVAL_SIZE)
                FCR_RETVAL[idx] = 0;
}

void
FCD_RS2320_ChangeHWBaud(MX_U
INT8 newbaud)
{
        RS232_1_UART_Update_Baud
(newbaud);
}

#include "D:\Program
Files\Flowcode\v5\CAL\includes.c"

//Macro implementations

void main()
{
        //Initialization
        adcon1 = 0x07;

        RS232_1_UART_Init( );
        //Call initialise function

        //Interrupt initialization code
        option_reg = 0xC0;

        //Comment:
        //Enable MCU led indicator

        //Output
        //Output: 1 -> B0
        trisb = trisb & 0xFE;
        if ((1))
        portb = (portb & 0xFE) |
0x01;
        else
                portb = portb & 0xFE;
```

```
	//Comment:
	//if sensor value is
	//00 = high
	//04 = middle
	//06 = low
	//07 = no water
	//for everything else is sensor
error

	//Loop
	//Loop: While 1
	while (1)
	{

		//Call Component
Macro
		//Call Component
Macro:
Serial_in=ReceiveRS232Char(10)
		FCV_SERIAL_IN =
FCD_RS2320_ReceiveRS232Char(10)
;

		//Decision
		//Decision: Serial_in =
0x31?
		if (FCV_SERIAL_IN ==
0x31)
		{

			//Input
			//Input: PORTA
-> LevelSensors
			trisa = trisa |
0x07;

	FCV_LEVELSENSORS = porta
& 0x07;

	//Switch
	//Switch: LevelSensors?
	switch (FCV_LEVELSENSORS)
	{
		case 00:
		{
	//Call Component Macro
	//Call Component Macro:

SendRS232String("High")
	FCD_RS2320_SendRS232Strin
g("High", 4);
	break;
		}
		case 04:
		{
	//Call Component Macro
	//Call Component Macro:
SendRS232String("Middle")

	FCD_RS2320_SendRS232Strin
g("Middle", 6);
break;
		}
		case 06:
		{
	//Call Component Macro
	//Call Component Macro:
SendRS232String("Low")

	FCD_RS2320_SendRS232Strin
g("Low", 3);
	break;
		}
		case 07:
		{
	//Call Component Macro
```

```
        //Call Component Macro:
SendRS232String("Empty")

        FCD_RS2320_SendRS232Strin
g("Empty", 5);
        break;
        }
        default:
        {

        //Call Component Macro
        //Call Component Macro:
SendRS232String("Sensor Error")

        FCD_RS2320_SendRS232Strin
g("Sensor Error", 12);
        }
                }

//Call Component Macro
//Call Component Macro:
SendRS232Char(13)

        FCD_RS2320_SendRS232Char
(13);

//Output
//Output: 0 -> B0
        trisb = trisb & 0xFE;
if ((0))
        portb = (portb & 0xFE) |
0x01;
else
portb = portb & 0xFE;

//Delay
//Delay: 100 ms
delay_ms(100);
//Output
//Output: 1 -> B0
trisb = trisb & 0xFE;
if ((1))
portb = (portb & 0xFE) | 0x01;
else
portb = portb & 0xFE;
// } else {
                }
        }

mainendloop: goto mainendloop;
}

void MX_INTERRUPT_MACRO(void)
{
}
```

Visual Basic Program

```
Imports System
Imports System.IO.Ports 'Required to get the port strings
Imports System.IO

Public Class DrainageMonitor

    ' Declare public variables
    Dim StringSerial As String
    Dim PortOpenStatus As Boolean = 0
    Dim Filename1 As String
    Dim Nofile As Boolean = 0

    Private Declare Sub Sleep Lib "kernel32" (ByVal dwMilliseconds As Long) 'Get
msdelay

    ' ----------- DROP DOWN SELECTION FOR PORTS -----------
    Private Sub cbxPortName_DropDown(ByVal sender As Object, ByVal e As
System.EventArgs) Handles cbxPortName.DropDown

        cbxPortName.Items.Clear() 'Reset/clear port list before checking ports. So
that it won't just append.
        Dim ports As String() = SerialPort.GetPortNames() 'Get all available ports
and place in a 1-dimentional array

        'Go through each of the available ports and place them in the dropdown
        For Each portName In ports
            cbxPortName.Items.Add(portName)
        Next

    End Sub

    ' ----------- START AQUISITION BUTTON -----------
    Private Sub BtnOpenPort_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles BtnOpenPort.Click

        'Enables serial port to be opened.
        If PortOpenStatus = 0 Then 'If off(0) then it will turn in on on(1)
```

```
            SerialPort1.PortName = cbxPortName.SelectedItem.ToString()
            SerialPort1.Open()
            SerialPort1.DiscardInBuffer() 'clear buffer
            Timer1.Enabled = True
            PortOpenStatus = 1
            SerialPort1.Write("A")

        Else
            MsgBox("Port already open!") 'if port was already opened and user tried
to opened it again.

        End If

    End Sub

    ' ----------- E-STOP BUTTON -----------
    Private Sub Button2_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button2.Click

        If SerialPort1.IsOpen = True Then
            SerialPort1.Write("B") 'Turns OFF Relay
            SerialPort1.Close()
            Timer1.Enabled = False
            PortOpenStatus = 0
            MsgBox("STOP PRESSED!!")  'Alert the user that the stop has been
pressed
        Else
            MsgBox("Port Closed")
        End If

    End Sub

    ' --------------- START MONITORING BUTTON ---------------
    Private Sub Button4_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button4.Click

        If Timer1.Enabled = True Then
            Timer2.Interval = TbxTimerInterval.Text  'Get the interval from the
interval input box
```

```
            Timer2.Enabled = True
            If Nofile = False Then
                MsgBox("No log file will be created.") 'If there was no log file created
initially
            End If
        Else
            MsgBox("Connect To device first")  'Must press "Start Aquisition' first!
        End If

    End Sub

    ' --------------- STOP MONITORING BUTTON ---------------
    Private Sub Button5_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button5.Click

        Timer2.Enabled = False  'Disable timer2
        TbxFilename.Text = ""  'Clear the log file text box after pressing "Stop
Monitoring"

    End Sub

    ' --------------- CHECK SENSOR BUTTON ---------------
    Private Sub Button1_Click_1(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button1.Click

        If Timer2.Enabled = True Then
            MsgBox("Stop Monitoring first!")  'Must stop monitoring first before you
can check sensor status
        Else
            If SerialPort1.IsOpen = True Then
                SerialPort1.Write("1")  'Writes 1 to the port to verify it is detected
            Else
                MsgBox("Port is Closed!") 'If port is closed, alert the user
            End If
        End If

    End Sub

    ' --------------- CREATE LOG FILE BUTTON ---------------
```

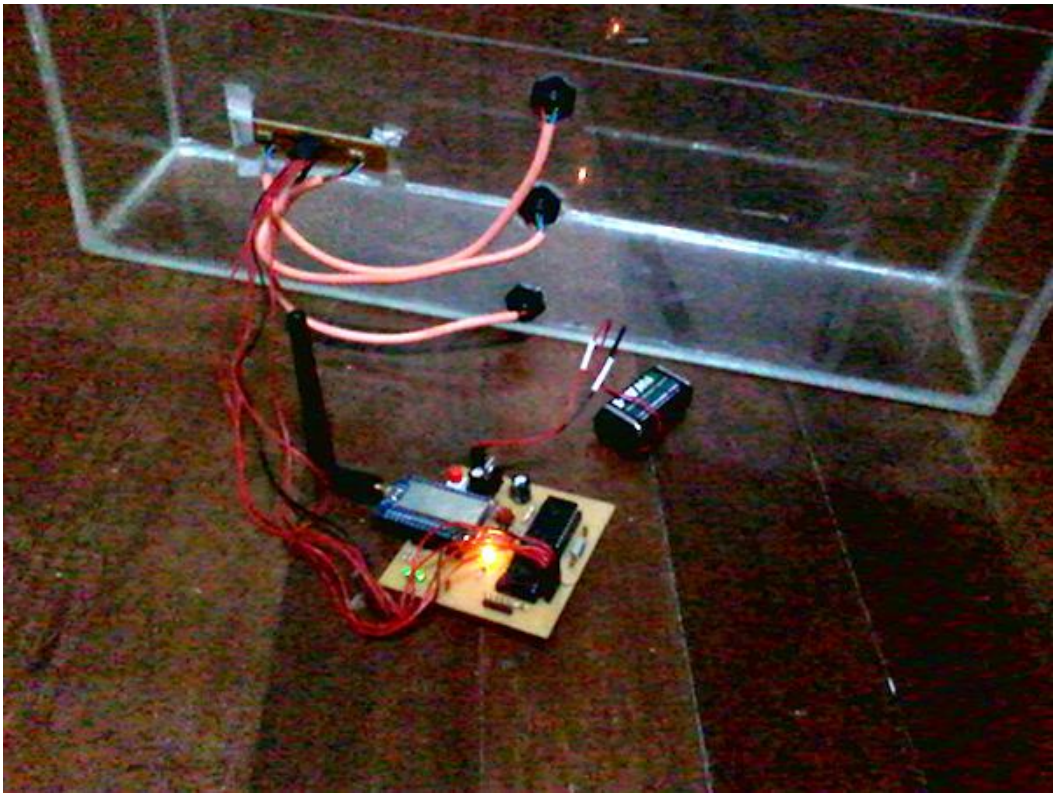
```
    Private Sub Button6_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button6.Click

        Filename1 = TbxFilename.Text  'Get the filename of the file to be created
        Filename1 = "C:\" + Filename1 + ".Txt"  'Save the log file at this location

        Using writer As StreamWriter = New StreamWriter(Filename1)  'Initialize
streamwriter
            Nofile = True  'true, meaning log file is created
            MsgBox("file created at " + Filename1)  'alert the user of the location of
the created log file
        End Using

    End Sub

    ' --------------- DISCONNECT AND EXIT BUTTON ---------------
    Private Sub Button3_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Button3.Click

        'Disconnect the port
        If SerialPort1.IsOpen = True Then
            SerialPort1.Write("B") ' Turns OFF Relay
            SerialPort1.Close()
            Timer1.Enabled = False
            PortOpenStatus = 0
        End If

        End  'Exit program

    End Sub

    ' --------------- CHECK SENSOR BUTTON ---------------
    ' Outputs sensor status in the tbxRawData
    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As
System.EventArgs)

        Dim buffersize As Integer
        buffersize = SerialPort1.BytesToRead
```

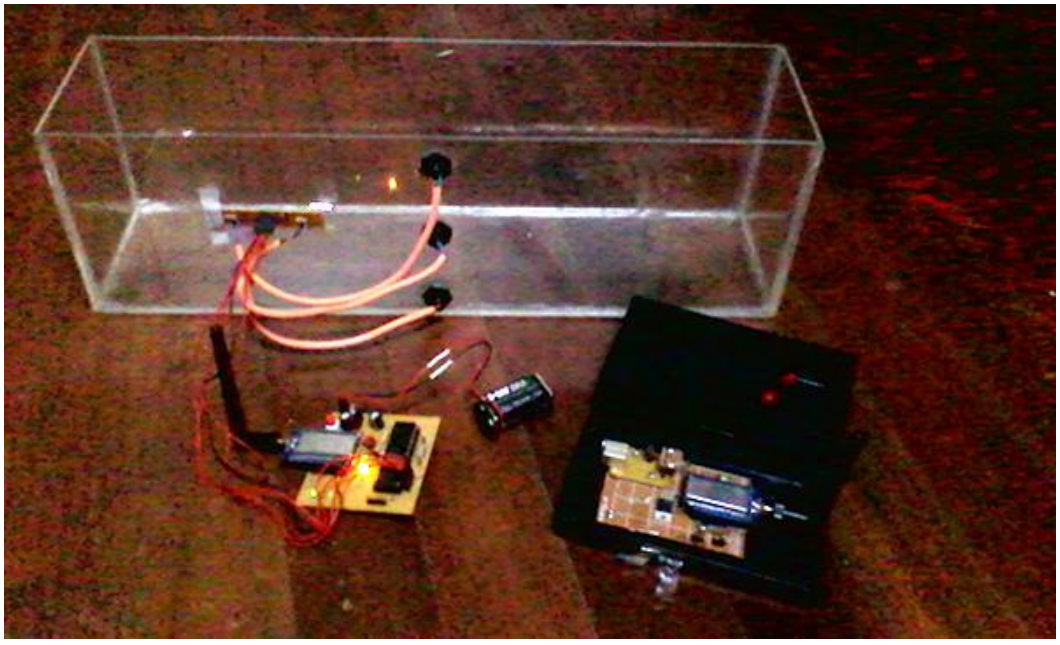
```
        tbxRawData.Text = buffersize  'Outputs the sensor status in the "Sensor
Status" text box

    End Sub

    ' --------------- WRITE TO LOG BOX ----------------
    Private Sub Timer1_Tick(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Timer1.Tick

        Dim buffersize As Integer
        buffersize = SerialPort1.BytesToRead
        If buffersize > 0 Then
            StringSerial = SerialPort1.ReadExisting  'Read the port data
            tbxRawData.Text = StringSerial  'Output the port string data
            TbxLogger.Text = DateString + "," + TimeOfDay + "," +
tbxRawData.Text + vbCrLf + TbxLogger.Text  'Output to logger box

            If TbxFilename.Text = "" Then
                Nofile = False  'If logfile input box is empty, no log file will be created
            Else
                'If log file was created, write the contents of the logger box to the log
file
                If Nofile = True Then
                    Using writer As StreamWriter = New StreamWriter(Filename1,
True)
                        writer.WriteLine(DateString + "," + TimeOfDay + "," +
tbxRawData.Text)
                    End Using
                End If

            End If
        End If

    End Sub

    ' --------------- TIMER2 --------------
    Private Sub Timer2_Tick(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles Timer2.Tick
```

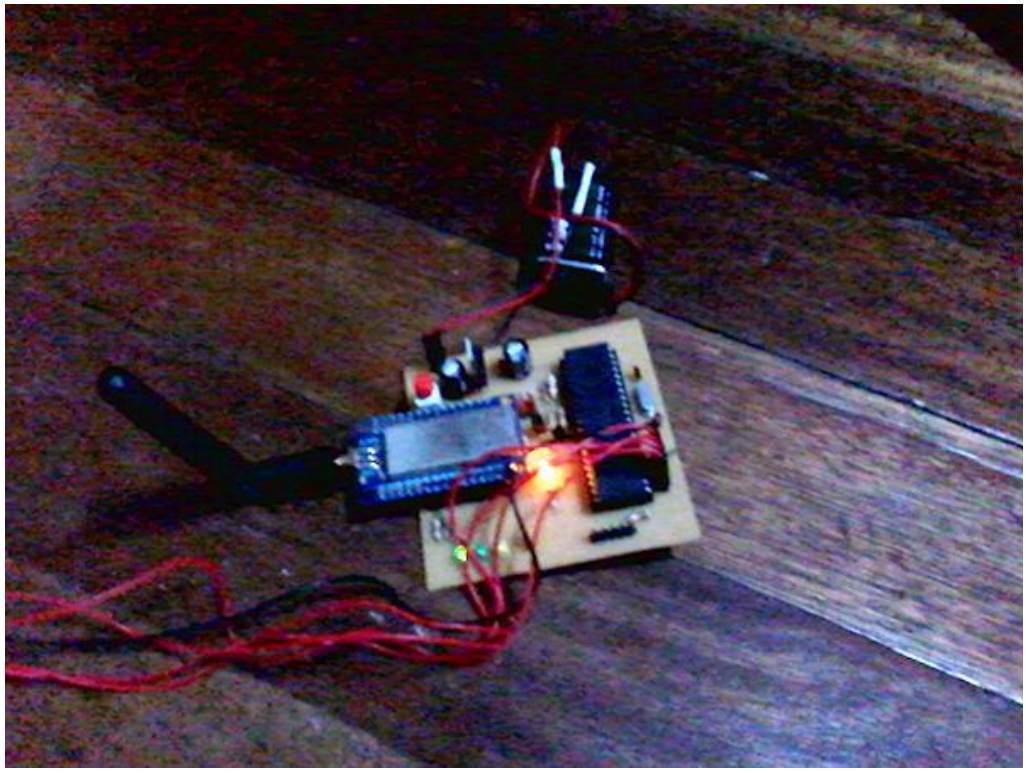
```
        ' Check the port at timer2 interval
        If SerialPort1.IsOpen = True Then
            SerialPort1.Write("1")    'Writes 1 to the port to verify that the port is still
opened
        Else
            MsgBox("Port is closed!")   'Alerts the user if the port was disconnected
        End If

    End Sub

End Class
```

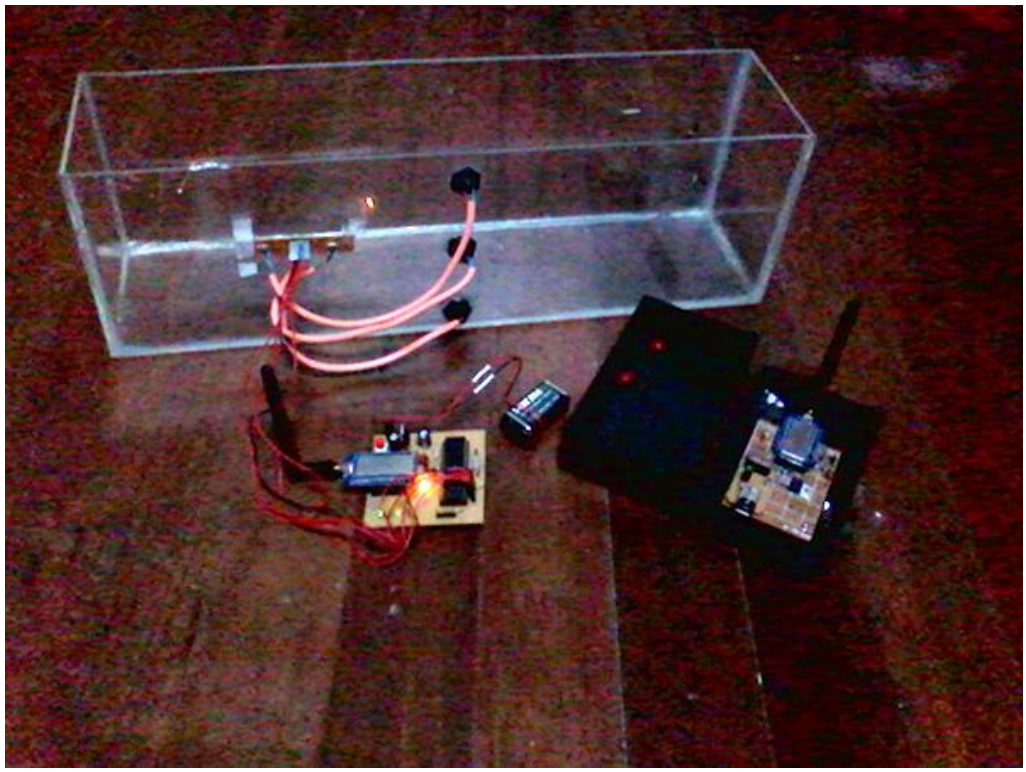
APPENDIX D

PICTURES OF PROTOTYPE









APPENDIX E

A Wireless Sensor Network for Monitoring of Water Level on Drainage Systems using ZigBee

Ani, Meynard Frizth A.

Chua, Divina A.

Cuna, Michael John A.

Abstract - Clogged drainage systems are the major cause of pollution and frequent flooding in Metro Manila especially during the rainy season. Thus, it is required to routinely monitor the condition of these drainage systems. The proposed system provides a way to monitor remotely drainage conditions and inform authorities of these conditions. This design presents an implementation of wireless sensor network in the monitoring of drainage systems using ZigBee. The use of ZigBee in wireless sensor network provides low cost, low power consumption, flexible and reliable network which is fast and easy to deploy. Blockages in drainage systems are detected through monitoring of water levels inside the drainage. The design consists of water level sensors which read the water levels and the ZigBee module is used to wirelessly send this information back to a central computer that monitors all drainages throughout the area.

Keywords: drainage systems, monitoring, wireless sensor network, ZigBee, water level

I. INTRODUCTION

Clogging of drainage is a major cause of both flooding and pollution in Metro Manila. Flooding is one of the main problems in the metro. This problem can result to even bigger disasters, such as deaths and damage to properties. Hence, providing an early warning device is one of the measures to prevent such disasters. The detection of drainage condition is routinely required in order to be informed on the best course of action that provides a solution to this critical problem. According to the Metro Manila Development Authority (MMDA), drainage and sewerage functions are combined in other countries unlike here in the Philippines where it is separate. The sewerage handles human waste and other liquid waste coming from households, while the drainage handles liquid waste coming from streets, factories, creeks, etc. This design project is based on the areas being handled by the MMDA.

Some of the existing systems today are for flood detection and control. This proposed system is focused more towards prevention rather than control. In the article "Development of Robotic Sewerage Blockage Detector Controlled by Embedded Systems" (Shrivastava, 2012), a remote controlled robot is attached with sensors for monitoring blockages in sewer pipelines. They used ultrasound sensors to detect blockages. On the other hand, this design uses sensors to detect water and waste levels in the drainage, thereby allowing the possibility of detecting blockage in the waterway. This approach in detecting blockages is different because water level sensors are used to detect overflow in the drainage. The introduction of wireless technology for flood monitoring will provide effective warning and response system. No manual checking will be needed because information about the water level is sent directly to a computer application.

The main objective of this study is to design a ZigBee-based wireless system that provides an easy way to monitor drainage conditions by water level. Specifically, the study aims to create a software application that gets and displays the current water level.

The scope of this design is to monitor the drainage condition using a ZigBee wireless

network with water level sensors. The water level sensors are set to certain levels – i.e. high, medium, and low. These are used to monitor the water level condition. It is limited only to monitoring and does not include flood control. Another limiting factor of this design project is that it only detects flooding due to increasing water level and does not detect actual level of solid waste sediments.

This design will impact on providing a more prepared and safe environment, as well as the health and safety of the people in local cities. The design will be useful for monitoring flash floods too. Also, by using wireless sensor network for monitoring of drainage, a simple implementation of wireless technology is presented.

The implementation of ZigBee in wireless sensor networks has the following advantages: low power consumption, flexible and reliable network, and fast and easy deployment. ZigBee-based wireless sensor network will provide a means to monitor the drainage condition, and sends information back to a central server. This allows easy monitoring of the condition of the drainage and will allow authorities to accurately plan and carry out necessary actions.

II. RELATED LITERATURE

There has been little research regarding wireless sewer monitoring, many of the sewer monitoring systems today still use mechanical methods. Previous studies use ZigBee added with other signal technologies for monitoring. On the other hand, this study uses ZigBee, together with water sensor technology. The study is composed of three main parts: the water sensor, ZigBee, and the microcontroller unit. The chapter discusses all three of those as well as previous related studies that were used as reference for this study.

Wireless Sewer Monitoring

Sewer network is prevalent in all cities and towns and is an underground facility. Earlier sewer systems were designed using the masonry materials and the current sewer systems are designed using the pipes (Shrivastava, 2012). Sewer flooding and pollution incidents are significant issues in the wastewater business process in the water industry. One of the most pressing issues for prevention of sewer flooding and pollution is sewer and gully blockages. Monitoring and maintaining the sewer are important parts of many water companies business to prevent catastrophic failures that can shut down a facility. Currently, many water companies have deployed telemetry systems to replace some of the manual operations, running costs remain expensive. Low cost wireless sensors may be the only cost-efficient option to replace traditional visual inspection which is extremely inefficient and costly. Low cost and low power sensors could be deployed over an extensive footprint network and provide early warning of impending failure offering time for maintenance teams to prevent service or regulatory compliance failure (Horoshenkov, Tait, Abd-Alhameed, Hu, Elkhazmi, Gardiner, 2009).

A practical implementation of a low-cost wireless Wireless Sensor Network (WSN) is by using Zigbee communication and acoustic sensor technologies to monitor the water level of the gullies. A Zigbee based short range WSN was selected for this application due to its attractive features such as low data rate, low power consumption, simple communication infrastructure, low latency and capability to support one master and up to 65000 slave control units.

There are two ways of using a sonic transmission to detect the water level, i.e. (i) by measuring the time of flight from transmitter to receiver – it will be faster in water, (ii) by using the level of the received signal – the received signal will be louder if the transmitter and receiver are both under water. Both of these methods of detection will require a driver for the acoustic transmitter and an amplifier for the received signal (Horoshenkov, Tait, Abd-Alhameed, Hu, Elkhazmi, Gardiner, 2009).

Liquid Level Sensor

Liquid level sensors detect the level of substances that flow, including liquids, slurries, granular materials, and powders. Fluids and fluidized solids flow to become essentially level in their containers (or other physical boundaries) because of gravity whereas most bulk solids pile at an angle of repose to a peak. The substance to be measured can be inside a container or can be in its natural form (e.g., a river or a lake). The level measurement can be either continuous or point values. Continuous level sensors measure level within a specified range and determine the exact amount of substance in a certain place, while point-level sensors only indicate whether the substance is above or below the sensing point. Generally, the latter detect levels that are excessively high or low (Deeter, 2009).

There are many physical and application variables that affect the selection of the optimal level monitoring method for industrial and commercial processes. The selection criteria include the physical: phase (liquid, solid or slurry), temperature, pressure or vacuum, chemistry, dielectric constant of medium, density (specific gravity) of medium, agitation, acoustical or electrical noise, vibration, mechanical shock, tank or bin size and shape. Also important are the application constraints: price, accuracy, appearance, response rate, ease of calibration or programming, physical size and mounting of the instrument, monitoring or control of continuous or discrete (point) levels.

LED and optoschmitt chips are sealed into the base of a clear plastic dome in such a position that light is normally, totally, internally reflected from the dome boundary to the optoschmitt. Thus, the output is normally high. When liquid covers the dome, the change is refractive index at the boundary means light escapes into the liquid, less light reaches the optoschmitt which turns off (Deeter, 2009).

ZigBee

ZigBee is a technology following IEEE 802.15.4 protocol. Low complexity, low cost, low power consumption, low transmitting rate, high reliability, wireless short distance transmission (compared with global Internet), and being capable of ad-hoc networks are all its features (Ruan Qiang, Xu Wengsheng, Wang Gaoxiang, 2011). ZigBee is a specification for wireless personal area networks (WPANs) operating at 868 MHz, 902-928 MHz, and 2.4 GHz. A WPAN is a personal area network (a network for interconnecting an individual's devices) in which the device connections are wireless. Using ZigBee, devices in a WPAN can communicate at speeds of up to 250 Kbps while physically separated by distances of up to 50 meters in typical circumstances and greater distances in an ideal environment. ZigBee is slower than Wi-Fi and Bluetooth, but is designed for low power so that batteries can last for months and years.

ZigBee provides for high data throughput in applications where the duty cycle is low. This makes ZigBee ideal for home, business, and industrial automation where control devices and sensors are commonly used. Applications well suited to ZigBee include heating, ventilation, and air conditioning, lighting systems, intrusion detection, fire sensing, and the detection and notification of unusual occurrences. ZigBee is compatible with most topologies including peer-to-peer , star network , and tree networks, and can handle up to 255 devices in a single WPAN (Margaret Rouse, 2006).

ZigBee and IEEE 802.15.4

ZigBee technology is a low data rate, low power consumption, low cost; wireless networking protocol targeted towards automation and remote control applications. IEEE 802.15.4 committee started working on a low data rate standard a short while later. Then the ZigBee Alliance and the IEEE decided to join forces and ZigBee is the commercial name for this technology.

ZigBee is expected to provide low cost and low power connectivity for equipment that needs battery life as long as several months to several years but does not require data transfer rates as high as those enabled by Bluetooth. In addition, ZigBee can be implemented in mesh networks larger than is possible with Bluetooth. ZigBee

compliant wireless devices are expected to transmit 10-75 meters, depending on the RF environment and the power output consumption required for a given application, and will operate in the unlicensed RF worldwide (2.4GHz global, 915MHz Americas or 868 MHz Europe). The data rate is 250kbps at 2.4GHz, 40kbps at 915MHz and 20kbps at 868MHz (Sinem Coleri Ergen, 2004).

IEEE and ZigBee Alliance have been working closely to specify the entire protocol stack. IEEE 802.15.4 focuses on the specification of the lower two layers of the protocol (physical and data link layer). On the other hand, ZigBee Alliance aims to provide the upper layers of the protocol stack (from network to the application layer) for interoperable data networking, security services and a range of wireless home and building control solutions, provide interoperability compliance testing, marketing of the standard, advanced engineering for the evolution of the standard (Sinem Coleri Ergen, 2004).

III. DESIGN PROCEDURES

The operation of the proposed active ZigBee based wireless sensor network for monitoring of drainage is to monitor the drainage condition for an early flood response. Figures 3.1 and 3.2 illustrate the block diagram of the water level sensor and the main server part of the design project, respectively.

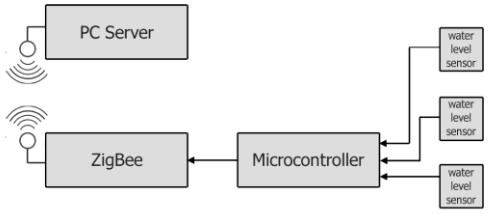


Figure 3.1 Block diagram of water level sensor

In Figure 3.1, the ZigBee will be programmed to act as a wireless personal network in which data will be sent to the main server wirelessly. The liquid level sensors will be programmed to monitor and to determine the water level condition inside the drainage. The liquid level sensors are positioned vertically to each other with certain distances - on the top, in the center, and below the acrylic container. They represent the water level condition in the drainage – high, medium, and low. Microcontroller will be used in order for the ZigBee to interpret the data given by the liquid level sensors and to send it wirelessly from the water sensor to the PC server and vice-versa.

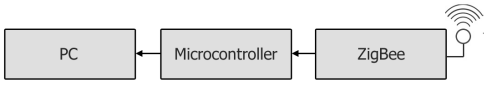


Figure 3.2 Block diagram of the PC server

Figure 3.2 shows the main server's ZigBee is programmed to be the network coordinator and to receive the data coming from the water level sensor. The microcontroller will be programmed to interpret the data coming from the ZigBee and to pass in to the main server. The server will have a program coded using Microsoft Visual Basic that is responsible for processing the data and displays it in its graphical user interface. Since the network is connected using mesh networking, only one ZigBee will be assigned as the coordinator and every other one will just have to transmit the data until it reaches it.

The software will be coded using Microsoft Visual Basic. It will have a graphical user interface for controls and data output.

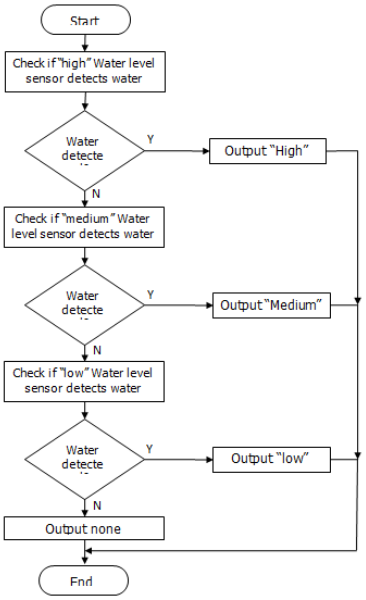


Figure 3.4 Program flowchart

IV. RESULT

Sensor Accuracy Testing

The water level sensor has its own sets of conditions to work; it should be able to touch water for it to function. In this test, the sensor will be blocked by materials that affect the sensor's reading ability. Each test will have three sets of trials in which it will determine if the three sensors are able to function correctly despite the obstacle. The first test will have no barrier for the sensor; the water level should be filled enough to touch the three sensors and each of them should be able to detect the water. The procedure for the remaining tests will be the same as the first one. The only difference is each of the remaining tests has different barriers for the sensors. If a sensor is broken, it should output 'sensor error' instead of not outputting any result. Table 4.1 shows the results of the sensor accuracy testing.

Table 4.1 Sensor Accuracy Testing

		Sensor Reading		
Test	Barrier	LOW	MID	HIGH
1	No barrier	YES	YES	YES
2	Paper	YES	YES	YES
3	Bottle	NO	NO	NO
4	Plastic	NO	NO	NO

Based on the results, if there is no barrier the sensor is able to easily detect the water and no problems are encountered. The material is able to read the paper because the water can pass through the paper. Also the reading of the sensor depends on the thickness of the paper, when water can't pass through the paper there will no reading in the sensor. When there is a barrier like bottle, or plastic material, the sensor is not able to read anything. The reason is because the sensor needs to touch the water for it to have a reading. The sensor works when the water is touching it. The sensor is activated by the reflection of the water coming from its photo diode reading. So, any barrier facing the sensor will affect its reading or there will be no reading at all.

Signal Integrity Testing

ZigBee modules have different maximum range based on its manufacturer data sheet. This test will determine the maximum range of the ZigBee module having barriers and obstacles along its way. The tests to be conducted will be systematic where each will have three trials, and each having a different test condition. The first test is with no obstruction - the maximum range will be measured when there is no obstruction present. The following tests which will have obstructions will be tested and the maximum range will be determined. The obstructions to be tested for the system are glass, enclosed room, drawer, and door. Table 4.2 shows the result of the signal integrity testing.

Table 4.2 Signal Integrity Testing

		Maximum Range		
Test	Container	Trial 1	Trial 2	Trial 3
1	No obstruction	60M	55M	58M
2	Glass Panel	55M	52M	58M
3	Enclose Room	30M	21M	25M
4	Steel	25M	28M	26M
5	Door	29M	25M	27M

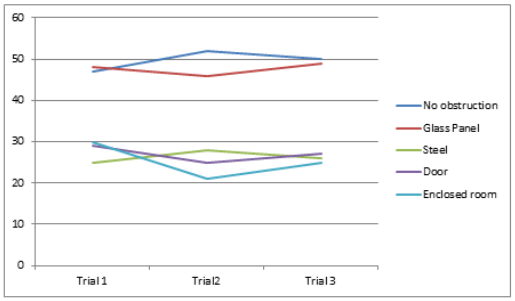


Figure 4.1 Graphical representation of the signal integrity test

Figure 4.1 illustrates the graphical representation of the signal integrity testing. The data is collected by measuring the maximum distance of the two ZigBee modules. The measurement is done manually using a measuring tape where this measures the end-to-end distance between the two modules. Based on the results, the maximum range of the ZigBee can be achieved when there is no obstruction. For those with obstruction, the glass panel has the strongest range, meaning that the signal of the ZigBee can easily pass through the glass panel. The other obstructions have the same or close values because the signal is not able to pass through easily to those obstructions. The enclosed room have the weakest range because the ZigBee signal is greatly affected by the surrounding concrete and steel.

V. CONCLUSION

Monitoring drainage systems conditions remotely provide an easier, safe and efficient way of monitoring. In this design the researchers are able to present a wireless sensor network for monitoring of water level in the drainage systems using ZigBee. The system is capable of monitoring the water level in drainage systems remotely through the use of ZigBee. The designers approach in monitoring the drainage conditions is through the use of water level sensors which are read as low, middle, and high by the corresponding program done in VB.Net. Test simulations on the design show the effective range of the system to its remote server and the accuracy of reading of the sensors. The system implements the wireless network using ZigBee modules because of its efficiency and low power consumption.

V. CONCLUSION

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